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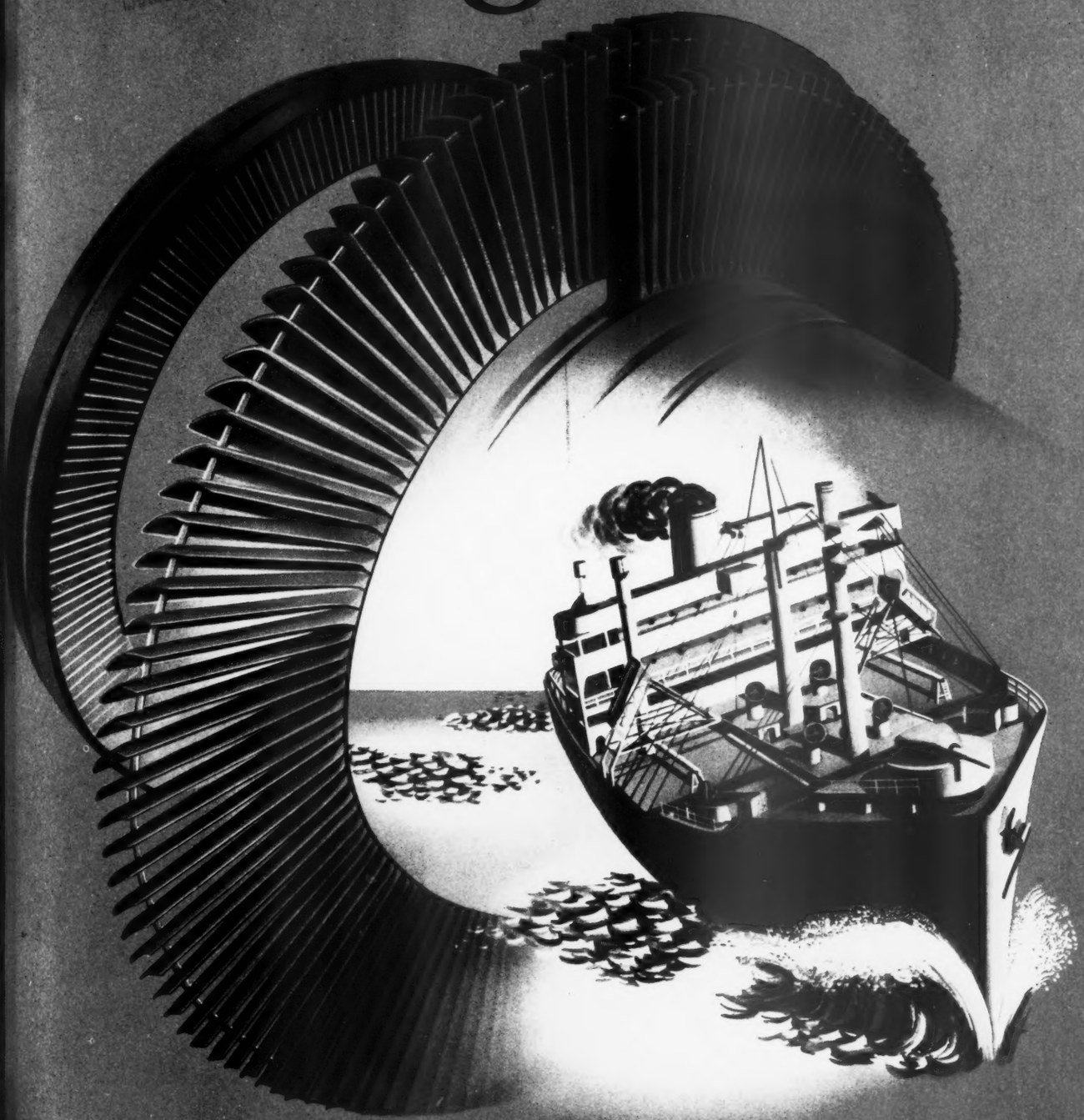


SEPTEMBER 1944

Mercury Vapor

. . . VERSATILE ENGINEERING MATERIAL

In engineering, as in medicine and elsewhere, mercury is one of the most valuable of nature's elements. Aside from liquid mercury, the vapor of mercury has increasing uses as an engineering material, particularly by electrical engineers.

Mercury vapor is being used as a copartner with steam as a heat-transfer medium in the boilers of two power plants. In pool-type rectifiers, mercury vapor is the pack horse that gives electrons a one-way ride from the liquid cathode of mercury to the anode. Mercury-arc rectifiers, particularly of the ignitron type, are being used by the thousands to provide large quantities of direct current from alternating current.

That passage of electric current through mercury vapor gives a brilliant light has been known for a hundred years. Practical use was made of this in the Cooper-Hewitt lamp introduced in 1900, the forerunner of the present mercury-discharge lamp. A significant fact of the Cooper-Hewitt lamp is its low pressure, a small fraction of an atmosphere.

As is the case with the passage of current through most vapors, the visible radiation occurs at only a few sharp lines in the spectrum. At ordinary pressures, i.e., from a small fraction of an atmosphere up to several atmospheres, the radiation occurs in the invisible ultraviolet, and in the yellow and green visible portions of the spectrum. The absence of radiation in the other spectral regions, particularly red, is responsible for the characteristic blue-green color of light from mercury vapor. As the pressures and temperatures are increased, the proportion of light outputs shifts toward the longer wave lengths and faint lines, almost absent at low pressures, become stronger. If pressures and temperatures could be raised high enough continuous spectrums, approaching those of sunlight, would be possible with mercury vapor.

At pressures of a small fraction of an atmosphere (from 8 to 20 microns) 60 percent of the electrical energy supplied to the lamp is converted to radiation at 2537 Angstroms (ultraviolet). Great use is made of this fact in two totally different ways. Radiation at 2537 Angstroms wavelength happens to be lethal to bacteria and viruses. Hence electrical discharge through low-pressure mercury vapor confined within special glass walls capable of transmitting this radiation invisible to the human eye is used as a bacteriacide. The widely used Sterilamp is of this sort.

The strong ultraviolet radiation of low-pressure mercury vapor has a second use. While itself invisible, the ultraviolet can be made into an extremely efficient light source. Certain rock dusts and synthetic organic phosphors have the ability to absorb these short radiations and transform them into longer waves, in the visible spectrum. These are the fluorescent lamps. They are low-brightness light sources of efficiencies of from two to many times that of incandescent lamps, depending upon the phosphors (i.e., colors).

Several so-called high-pressure mercury-vapor lamps have become commercial and practical in the last eight years for photoengraving work, airport ceiling projectors, etc. These have been the 250-watt and 400-watt units, and now, as discussed in this issue, the 3000-watt lamp. In these the pressures are of the order of one half to one atmosphere. With these lamps about one sixth of the radiation is in the invisible spectrum, about one third is in the yellow, and about one half in the green. The efficiency of these lamps runs about 40 lumens per watt. (Incandescents: 10 to 15 lumens per watt). The temperatures in these lamps runs pretty high. The average arc-stream temperature is about 10 000 degrees F, while the temperature near the glass walls is about 700 degrees F.

The desirable characteristics available at still higher pressures are obvious, but entail many practical difficulties, particularly those of cooling. A great deal of research work has been done in this direction. If practical difficulties could be resolved, a lamp of say five atmospheres pressure would be half again more efficient than the one-atmosphere lamp of the preceding paragraph.

At extremely high pressures—of several hundred atmospheres—some expedient such as water cooling must be adopted to prevent recrystallization of the quartz walls. (Quartz recrystallizes at about 1500 degrees F and melts at about 3000 degrees F). Although the complication of water cooling and high voltage limits their usefulness, 1000-watt water-cooled mercury-vapor lamps have been used commercially where extreme concentrations of light are desirable. Such a lamp has an inside diameter of a twelfth of an inch, requires about one and a half amperes at about 900 volts. The efficiency is 60 lumens per watt.

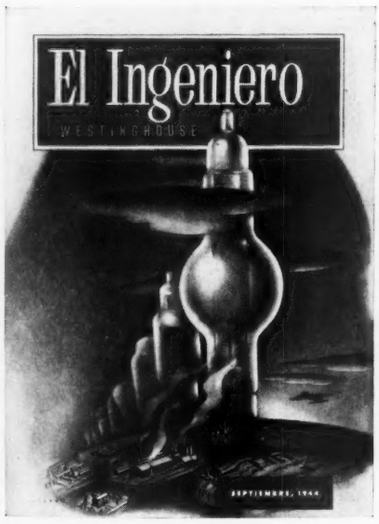
High-pressure lamps of still higher voltage are possible, with, of course, severely increasing practical difficulties. A 50-kw lamp would give a light of good color at an efficiency of 70 lumens per watt, but would require a potential of 50 000 volts which would present insulation problems.

WESTINGHOUSE Engineer

VOLUME FOUR SEPTEMBER, 1944 NUMBER FIVE

On the Side

The Cover—Supporting the feature article on the American Merchant Marine, the artist depicts the dependence of the merchant marine upon the steam turbine.



The *Westinghouse* ENGINEER is going internationalistic. The first issue of *El Ingeniero Westinghouse* is pictured above. It contains, in Spanish, articles from recent issues of *Westinghouse* ENGINEER chosen for their interest to Spanish-speaking readers. The new publication is being distributed bimonthly by the Westinghouse Electric International Co., among engineers of Mexico, the Caribbean islands, and Central and South America. Readers of the English edition of *Westinghouse* ENGINEER in Latin America who are interested in *El Ingeniero Westinghouse* should address their inquiries to Luis G. Núñez, Westinghouse Electric International Co., 40 Wall St., New York (5), U.S.A.

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In This Issue

THE AMERICAN MERCHANT MARINE 131

THE NEW SILICONE-RESINS INSULATIONS 138
G. L. Moses

STORIES OF RESEARCH 142
A New Paper-Capacitor Impregnant
Heat-Shock Testing
High-Temperature Fatigue Machine

THREE-KILOWATT MERCURY LIGHTING 144
W. H. Kahler

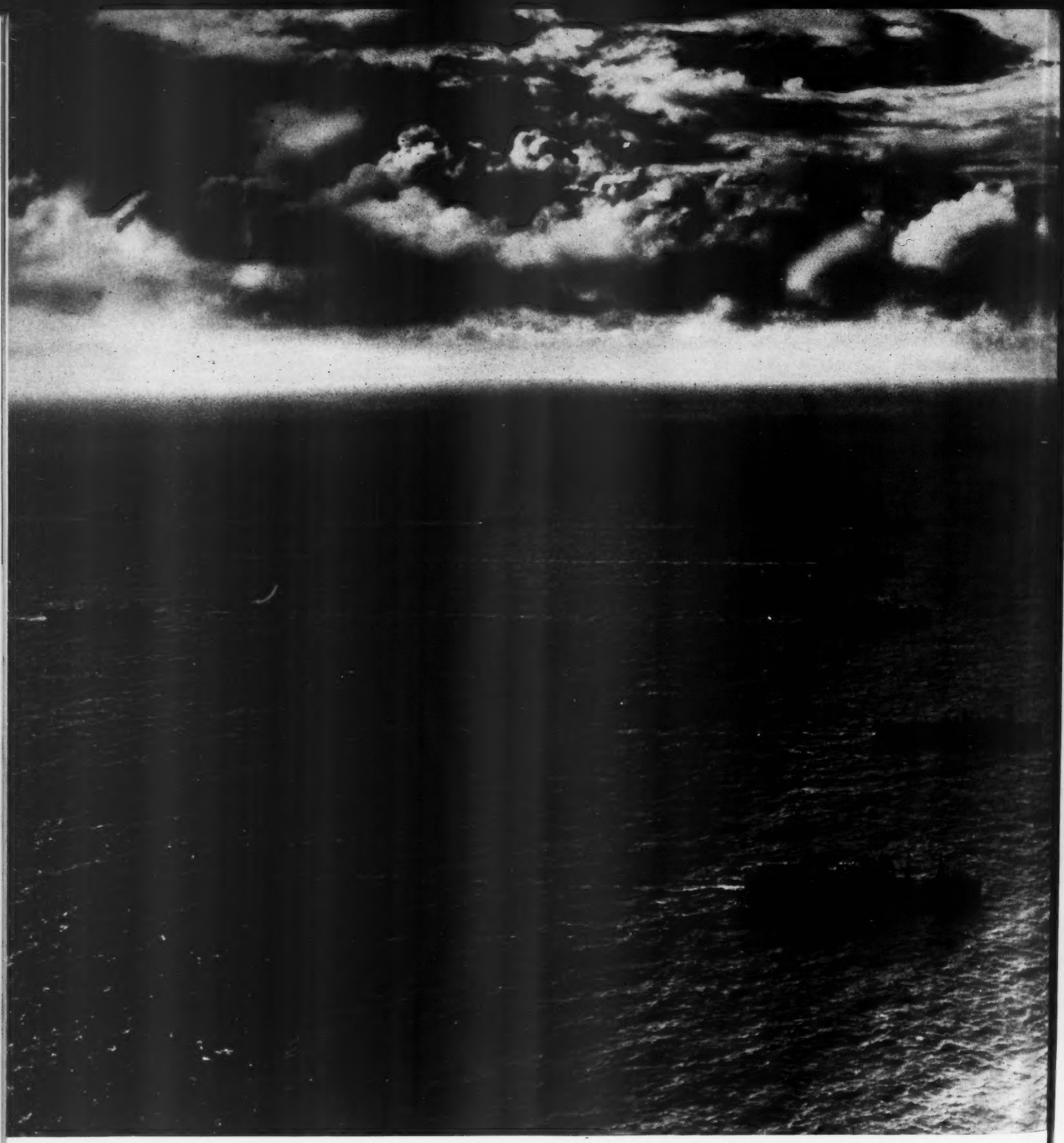
POWER-SYSTEM ECONOMIES 147
A. C. Monteith

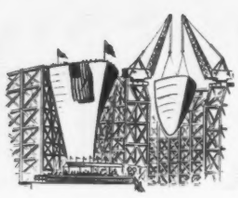
APPLICATION OF HIGH-VOLTAGE FUSES 153
H. L. Rawlins and *J. M. Wallace*

WHAT'S NEW! 158
Furnatron—Electronic Furnace Control
Industrial High-Frequency Generators
No-Blink Fluorescent Lamp Starter
An Improved Vibrometer
Smoke Generator for Airports
An Amplifier for Low-Impedance Output Devices

The *Westinghouse* ENGINEER is issued six times a year by the Westinghouse Electric & Manufacturing Company. Dates of publication are January, March, May, July, September, and November. The annual subscription price in the United States is $2.00; in Canada, $2.50; other countries, $2.25. Price of single copy is 35c. Address all communications to the *Westinghouse* ENGINEER, 306 Fourth Ave., P.O. Box 1017, Pittsburgh (30), Pennsylvania.

THE WESTINGHOUSE ENGINEER IS PRINTED IN THE UNITED STATES BY THE LAKESIDE PRESS, CHICAGO, ILLINOIS





Miles-long convoys bespeak victories of production and the heroism of merchant seamen. We have learned at great cost and close peril that a strong merchant fleet is as necessary in defending our way of life as is a strong army or navy. A large modern merchant fleet is equally necessary for our economic security.

American Merchant Marine Reborn

With the launching nearly every four hours of a new merchant vessel, the United States is creating a fleet unparalleled in size and excellence. Many ships are of the expendable, emergency class, but even without these the United States will end the war with top-ranking position among maritime nations, a position relinquished with the decline of the clipper ships. It is important that all Americans become well acquainted with this revitalized merchant marine.

THE MERCHANT fleet of the United States has alternately been our pride and our despair. At present it is our pride. It is now, and will be for some time after the war's end, the greatest fleet of ships—in quality as well as quantity—ever possessed by any nation. The U. S. merchant fleet is likely to be three-fourths as large as the entire combined prewar merchant fleets of the world, which was seventy odd million gross tons. What's more, almost all the ships will be comparatively new and many of them will be excellent ships as measured by peacetime standards. This is in marked contrast to the situation eight years ago when, of six leading maritime nations of the world, we ranked last in number of ships in foreign trade and in number of ships with an average speed of 12 knots or more, and fifth in total tonnage of ships and in number of ships younger than ten years.

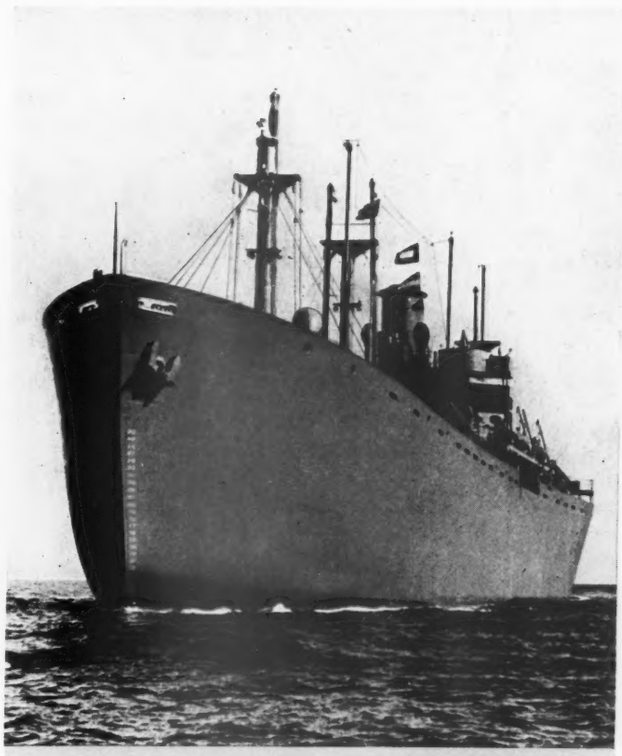
While the United States has been launching merchant vessels at the utterly fantastic rate of five each day, the merchant fleets of the other maritime nations have declined steadily in tonnage as a consequence of torpedoes, bombs, and other losses. The foreign ships that do survive will have aged greatly in war service. Except in the United States, building of merchant ships has been substantially nil or has not nearly kept pace with sinkings. England, which had nearly a fifth of the world's tonnage, has made but little headway in recouping its losses with new construction. By agreement with the United States, the shipyards of Britain are concentrating primarily on producing fighting vessels.

This is not the first time ships carrying the United States flag have dominated the ocean trade routes. How proud we were as youngsters, while studying American history, to read that our clipper ships were for so many years supreme in the maritime world. American-built and manned sailing vessels were the finest and fastest afloat, and as a result in 1830 nine-tenths of all our foreign trade was carried in American vessels. By 1850, the volume carried in American bottoms had declined approximately to three-fourths. The repeal of the subsidies laws in 1858 and the Civil War were body blows from which the American merchant marine has never recovered. In 1870, only a third of our commerce moved in American ships, and by 1890 it was but one-sixth. In 1910 it reached an all-time low of less than one-tenth.

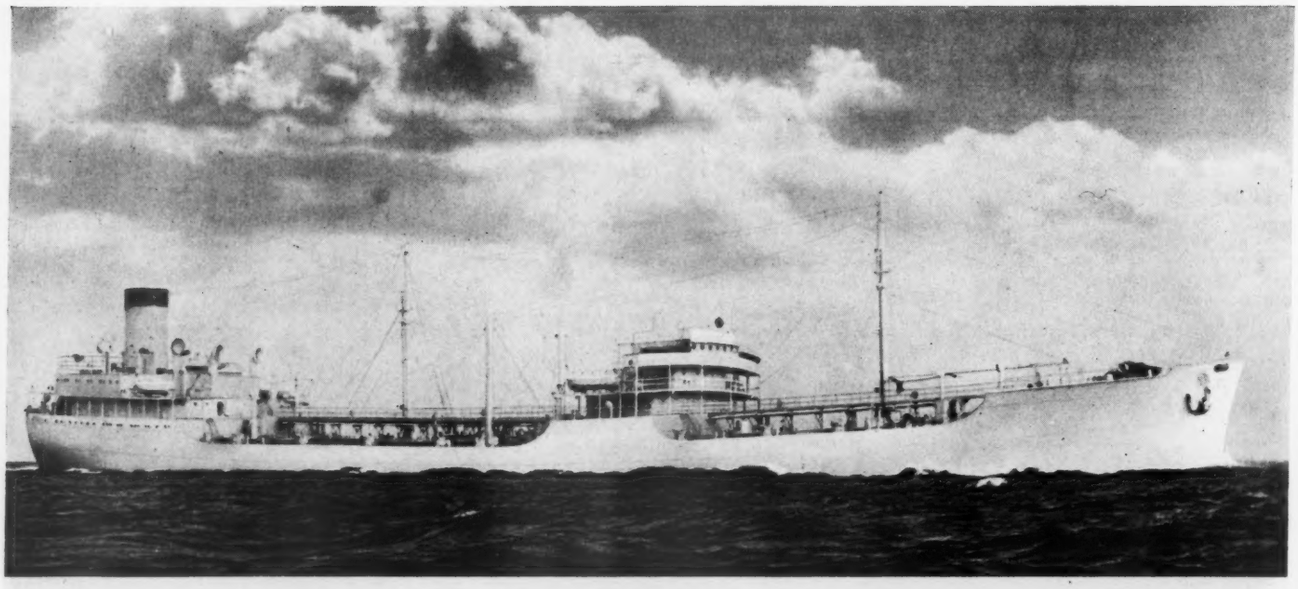
Came the first World War. Our fleet of less than two million gross tons in foreign service ranked fifth among the nations of the world. Thrust for the first time into a major war with an impoverished merchant fleet, a frantic shipbuilding program was begun. About 2500 commercial vessels, costing three billion dollars, were built, some of wood, destined never to see service. Pictures of literally acres of these emergency vessels rotting and rusting at anchor were painful reminders that something was horribly wrong with our merchant marine.

Although we promised ourselves after World War I that never again would we permit our merchant fleet to sink to such a low state, the decline began almost immediately. The tonnage of shipping in foreign trade in 1921 was 11 million gross tons. By 1925, it had dropped to nine and a half million, by 1930 to six and a half million, and by 1937 to two and a half million. In September, 1937, the total merchant fleet of the world was about 70 million gross tons. We were outranked in overseas trade by the British Empire with 13 million gross tons and, significantly, by the two Axis nations; Japan with three million and Germany with 2.8 million, and almost equalled by Italy and France. These American ships carried only one-fourth of our foreign trade. By way of contrast, the corresponding figures for the three Axis nations were: Japan, 70 percent; Germany, 58 percent; and Italy, 46 percent.

The inclusion of age makes the picture more dismal. In 1935, the average age of all U. S. merchant vessels was more than 15 years. This is old, considering a ship life of 20 years. As of April, 1937, only two cargo vessels for overseas trade had been built or contracted for in 14 years, and no passenger



A Liberty ship, riding high in the water, returns from a trial run. The Libertys have been the emergency ships of this war.



Among our finest tankers is the **USS Cimarron.** *Twin screws, each with a 6000-shp geared turbine, drive this 135 000-bbl tanker at 18 knots.*

or combination passenger and cargo vessels had been built since 1932. Nine-tenths of our merchant-marine fleet was destined to be obsolete by 1942.

The year 1936 was of great significance to the American merchant marine. Congress passed, in June of that year, the Merchant Marine Act (by the slim majority of eight votes). No one, not even its sponsors, could have dreamed how important that action was, for it gave us a priceless impetus toward the production of ships on which the fate of the democracies hung so precariously in 1942 and 1943.

The Merchant Marine Act of 1936, in effect, did two things. It took a realistic view of the need for, and manner of, giving federal aid to the merchant marine. Also it resulted in the establishment of an aggressive and capable Maritime Commission, which had both the vision and the power to act.

The Why of Government Aid to Shipping

The story of public aid to shipbuilding and shipping is no new one to the United States. The first session of Congress in 1779 granted customs discounts on goods if carried in American-owned bottoms, and also levied higher tonnage dues on foreign vessels. In the period between the Civil War and the first World War, Congress attempted on several occasions to reverse the steady decline in the merchant fleet by the passage of various forms of subsidies. Usually these took the indirect form of mail subsidies. None were more than briefly effective in staying the downward trend.

Congress in 1920 sought to develop shipping through temporary government operation and construction loans to private operators. This policy was augmented by a new federal law in 1928, which increased the construction loan fund and provided indirect subsidies through mail contracts. These measures were only slightly effective.

The bald truth of the matter is that, first, it costs more to build ships in American yards, and, second, it costs more to operate them under the American flag. Both of these come about mostly by the higher wages paid to American workmen and seamen. A ship that costs 15 million dollars, if built in an American yard where there is a car in every garage, might cost, under the bicycle economies of England or Holland, 10 million or less. In 1939 a skilled mechanic in a New Jersey shipyard received about seven dollars for an eight-hour day. A man doing similar work in a British yard got less than three. In Japan the wage was less than a dollar. The average monthly wage paid to able-bodied American seamen was, in 1939, about $72; to those on British ships, $48; German, $50; Japanese, $14. Likewise, our men were better fed, had better living quarters, and were surrounded by more safety devices.

The Merchant Marine Act of 1936 recognizes these two separate conditions of greater cost and undertakes to provide necessary compensation directly instead of indirectly through mail contracts or low-cost loans. First, the additional cost of constructing a ship in an American yard instead of a foreign yard, up to a maximum of 50 percent of the cost of the vessel, is underwritten by the Maritime Commission. In other words, Uncle Sam pays, if necessary, half the cost of a vessel built for foreign service in an American shipyard.

Second, a ship operator maintaining service in a recognized, competitive foreign trade route is reimbursed by the amount of additional cost of operating it under American standards as against those of the competing foreign lines. American ships receive no premium for carrying mail. By these devices, the Maritime Commission seeks to achieve for America, not an uneconomic competitive superiority but, as Admiral Land puts it, "parity" with foreign operators.

Actually, America's subsidized merchant marine before the war was rather small; it represented 13 percent of the ocean-going tonnage under the American flag. The remaining portion operated without government help. Vessels plying in coastwise and intercoastal trades are not eligible for differentials because foreign-owned vessels have been barred from this trade since 1815. Prior to June, 1941, when operating differentials were suspended for the duration, the total operational subsidies averaged about 12 million dollars a year. The operating subsidy for a 20 000 000-ton fleet, carrying one-half our foreign trade, would probably not exceed 50 000 000 dollars annually, which is small compared to the tariff protection given other industries less vital to the natural welfare.

A New Merchant Fleet Is Built

The Maritime Commission, soon after its establishment in 1937, recognized the deplorable physical state of the mer-

chant marine and took prompt and vigorous remedial action. It established a few basic designs for good, safe merchant vessels, incorporating the most advanced ideas in construction and design, and utilizing the most modern equipment. The result was the designs for three sizes of cargo vessels; the C1 of 5000 gross tons, the C2 of 6000, and the C3 of 8000. Also, several combination cargo and passenger vessels were designed and built, which were essentially modifications of the C3 design to suit the specifications of certain shipping lines. All these designs were and are basically sound, and introduced the element of standardization, which reduces the cost when more than one of that type is built.

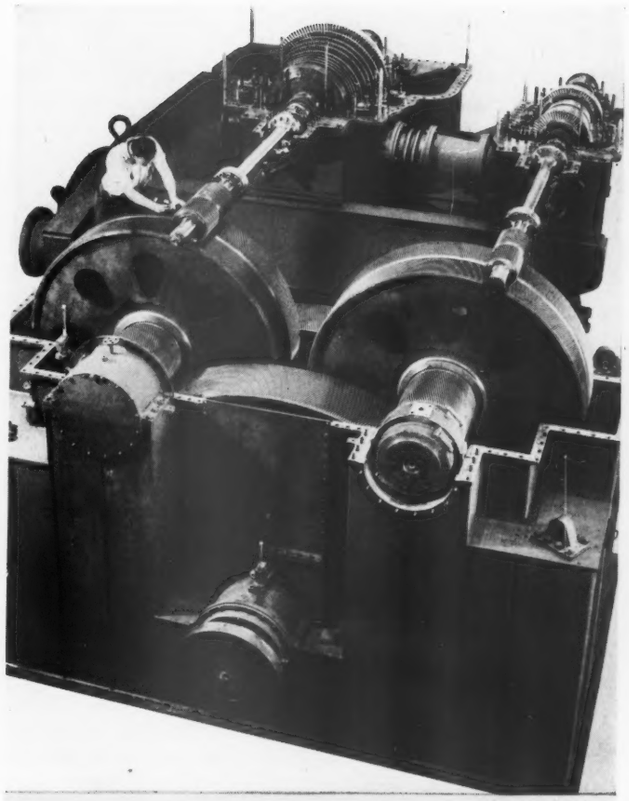
Maritime Commission studies indicated that 500 ships built over a ten-year period would provide the United States an adequate fleet of modern vessels to replace the old ones. The Commission took positive action by placing the initial order for C-class ships. The first C-type ship was launched in 1939. By October, 1940 forty-five passenger and cargo ships, tankers, and dry-cargo ships had been completed. The program to revitalize the merchant marine with 50 new ships a year was moving along smoothly.

The rumble of war drums began to press upon our ears. Would there be conflict and would we be involved? It seemed wise to speed up the shipbuilding program. The schedule of 50 new ships per year was doubled to 100 in August, 1939. The rumble became a roar and the program was doubled again to 200 in August, 1940.

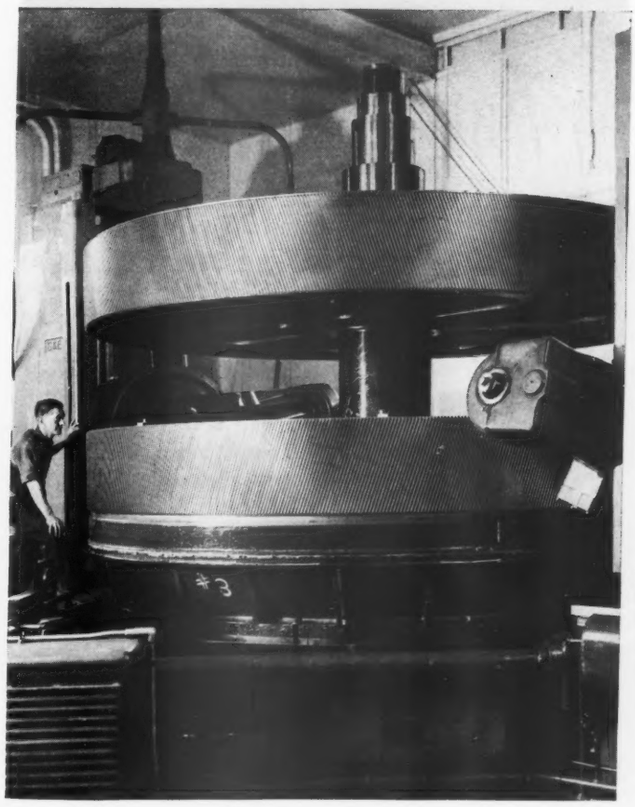
Meanwhile, England, her lifeline of ships threatened, ordered 60 cargo vessels of 10 800 deadweight tons from American shipyards. The design was an old one—fully fifty years—but it had been proved in service as adequate for the service intended, slow-speed cargo work. These ships were powered by Scotch boilers and reciprocating engines, which were more quickly obtainable than Diesel engines or turbines. Also the

TABLE I—COMPARISON OF MERCHANT VESSELS

	Length Feet	Bdth. Feet	Tonnage			Propulsion Machinery		Speed Knots	No. Pass.
			Gross	Dead-weight	Dis-placement	Type	SHP		
Liberty	441	57	7185	10 800	13 812	Steam Engine	2500	11½	0
Victory	455	62	7612	10 800	15 200	Geared Turbine	6000 8500	15.5 16.5	0
C1	413	60	5028	7500	12 875	Geared Turbine or Diesel	4000	14½	8
C2	459	63	6085	9758	13 900	Geared Turbine or Diesel	6000	16½	12
C3	492	69.5	7 773	12 595	17 600	Geared Turbine or Diesel	8500	18	12
C3 Cargo & Passenger	492	69.5	9300	9690	16 190	Geared Turbine	8500	16½	96
			8030	8850	16 725	Diesel		16½	196
American Export	473	66	6 736	9514	14 500	Geared Turbine	8000	16½	0
Miss. Shipping	491	65	7978	9021	14 200	Geared Turbine	7800	16½	67
Robin Line	450	66	6800	9600	15 200	Geared Turbine	6300	15½	12
Manhattan Washington	668	86	24 289	13 080 13 239	24 289 24 289	Geared Turbine	30 000	20½	1224
America	723	93	26 482	13 361	34 500	Geared Turbine	34 000	22	1202
Tankers 1 Screw	502 514	68	10 600	16 400 (129 000) bbl	21 000	Geared Turbine	12 000	18	0
Twin Screw	553	75	11 335	16 735 (145 000) bbl	23 338		13 500		



A rare picture this, as a turbine and its gear seldom meet in the factory. The high- and low-pressure turbines are at the upper right and left. Each drives a first-reduction bull gear, which combine to drive the second-reduction bull gear, just visible in the foreground. The power is delivered to the propeller through the shaft extending through the gear case, lower center. The view below shows the hobbing of a marine gear.



designs were all immediately available and lent themselves to adaptation for quantity production.

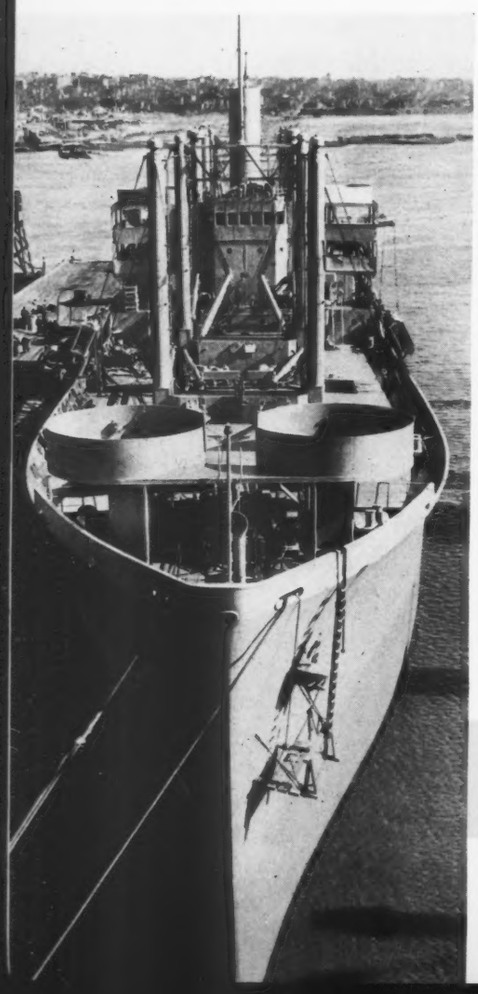
Before these ships for England were delivered, the full picture of our own desperate need for ships was spread before us. Obviously, the C-class program was woefully inadequate. An emergency-type vessel was needed in quantity, and quickly. Time, only, mattered. The awful successes of the U-boat made that painfully clear.

We turned to these ships being built for England. The blueprints were at hand; shipyards were already at work, in a preliminary way at least, on a mass-production basis. Steam reciprocating engines could be built quickly by many shops not participating in the Navy program, which, with the C-type ship construction program, had already swamped the builders of steam turbines and gears. This would be our World War II emergency, expendable ship; it would be our Liberty ship.

Welding replaced riveting. Because some yards produced several hundred ships from the same blueprints, production-line methods could be set up, whole sections of the ships could be prefabricated on the ground, where men can work more effectively, and the sections handled by crane. All this saved much time of incalculable value.

The first Liberty ship was launched in September, 1941. Then began the rapid succession of ship-building records that embellished our newspaper headlines, until the Libertys were being turned out in the phenomenal average time of 41.5 days, the record being 10 days. By the end of 1942, 544 Libertys had been built; in 1943, 1238 were finished; and this year, 739 are scheduled for completion. About 100 are planned for completion during the year 1945.

The Liberty-ship program was only superimposed upon the C-ship schedule; it did not replace it. The Liberty ship has been the draft horse of the sea; because of it we were not too late with too little. But, the Liberty ship has one serious defect. It is a slow ship, about 11½ knots indicated speed. What's more, speeds greater than that of submarines could not be obtained by increasing the power by larger or different propulsion machinery, such as geared turbines, even if they had been available. Attempting to push the blunt-nosed Liberty faster than about 13½ knots simply piles up a bigger bow wave. The Liberty's hull is inherently unsuitable for the moderate speeds of modern cargo vessels and nothing much can be done about it.



The **Nancy Lykes,** *a C2 vessel, gets final fitting out.*

Through the submarine gauntlet, a few knots more speed is often the difference between safe passage and destruction. The urgent need was for faster ships. So, without any slackening in Liberty-ship production, a new, faster ship was projected. It was to be known as the Victory ship. Essentially, it was similar to the Liberty hull, but with 15 feet added to the bow to give it finer lines (land folk call it streamlining). The beam was widened slightly for greater stability at the greater speed, but the cargo capacity was unchanged (more space is required for machinery). The same production-line methods and some of the same shipyards used for the Liberty are being utilized in the construction of the Victorys. Most important of all, her finer lines allow greater speed without an inordinate cost of horsepower. Geared turbines were ordered because the manufacturing capacity had been increased and the rate of productivity was stepped up by changing the gear design, so that geared-turbines can be had for all of these badly needed, faster ships without jeopardizing the fighting-ship and C-ship program. With 8500-shaft-horsepower gears and turbines, almost identical to those supplied to standard C3 vessels, the Victorys have a speed of more than 16.5 knots. Victorys for which the high-power turbines are not available are being equipped with 6000-shp turbines (similar to those for C2 vessels). With a speed of 15.5 knots, even the lighter powered Victory can outrun submarines.

The first Victory ship was launched early last January, and by next New Year's day, 300 should be in the water. The program for 1945 calls for 278 Victorys. As the fast Victory ships begin to come into the picture, production of Liberty ships tapers off.

Another element in the program is the construction of troopships for the Navy. They are driven by geared turbines. The announced program calls for 27 of these. Still another vessel, designed especially as a troop or cargo transport, is under construction for the Navy. This is known as the BD or BE and is propelled by electric motor-driven twin screws. Availability, again, largely dictated the choice of drive. At present, 64 of these are being built, and some have gone into service within the last two months.

The Merchant Fleet Adds Up This Way

By the end of 1944, we will have built about 2521 Liberty ships, 129 Victory ships. Including the prewar construction of C-class ships, the totals will be about as follows: C1, 166; C2, 230; C3, 88; combination C3 cargo and passenger, 23; and troopships, 227. To this fleet must be added 594 tankers of excellent design. This aggregates 3978 vessels of 45 150 387 deadweight tons and will have cost Uncle Sam about ten billion dollars. An estimated seven million deadweight tons will be added to this figure in 1945. These totals are to be compared with 1150 ships of 10 500 000 deadweight tons in foreign and domestic service when we entered the war.

Future losses are unknown, as are the length of the war and the construction beyond 1944. The size of the fleet when peace comes cannot now be definitely predicted. Unquestionably, however, it will be huge by prewar standards. Even subtracting the Liberty ships, whose future is an enigma, the American merchant fleet will probably equal or exceed the fleet under the English flag—and will be newer and more modern to boot.

The Particulars of the Vessels

The Liberty is clearly an emergency vessel. As cargo ships go, it is big, but by no means in the largest class. Its capacity is 10 800 deadweight tons, which places it between the C2 and the C3 in size. It is a sturdy, reliable ship. It is powered by a huge triple-expansion steam engine of 2500 hp, indicated. As

Victory ships are high-speed cargo vessels of good design. Driven by geared turbines, they will become part of the permanent merchant fleet.

compared with other modern drives, the engine is bulky and has an overall oil rate about double that of a turbine-driven ship. The Liberty, with its slow speed and high fuel consumption, will find it difficult to bear up in peacetime competition. Various suggestions have been made for their postwar use, even such as huge floating dockside warehouses, for sale to foreign lines that engage in tramp service, floating fish canneries, etc. But the problem of postwar disposition of Liberty ships remains unanswered.

The Victory is a good ship, measured by any standard. Some features of the C-class were sacrificed to suit it to mass-production methods, but it is a fast, competitive ship with modern propulsion machinery. All Victory ships are powered by geared turbines. (One experimental ship is being fitted with a 6000-shp direct-drive Diesel.) The Victory can be adapted to normal peacetime merchant-marine service without extensive machinery alterations.

The C-class vessels, being designed as part of a long-range program, are excellent. Many will require little more than an overhauling and new paint, but others that have been transformed into hospital ships, troopships, etc., will require considerable reconversion. The C-class vessels will form the nucleus of a strong, competitive U. S. merchant fleet.

Other types of vessels, such as the *America*, and other combination passenger-cargo vessels built before the war as part of the long-range shipbuilding program are now wearing the grey paint of transports. Those that survive the war and the new, specially built troopships and cargo transports can serve in postwar passenger and passenger-cargo service. To complete the picture, a few special types of vessels, built in small numbers, should be mentioned. These include self-propelled concrete cargo vessels, concrete barges, small coastal cargo vessels, and ocean tugs. They, however, will not be important in the overall program.

The tanker fleet is superb. By very good fortune—plus the enterprise of petroleum companies and the encouragement and aid of the Navy—a group of high-class, high-speed oil tankers was constructed in the five prewar years.

Oil tankers are of many types. The one major type built during the war is a single-screw vessel of 129 000 bbl with a 6600-shp turbine-electric drive. It has a speed of 14.5 knots. Other war-built tankers include 35 small coastal units and 57 Liberty ships modified to carry about 70 000 bbl of oil.

Before the war several Diesel-driven tankers were built as part of the Maritime Commission program. Also several excellent high-speed tankers were constructed before Dec. 7, 1941. These include a twin-screw 18-knot tanker with two 6750-shp geared turbines. Another type of high-speed tanker built at that time is a single-screw vessel with a single 13 000-shp geared-turbine drive.

How Merchant Vessels Are Driven

There are three types of main power plants used on merchant vessels—with a possible newcomer on the horizon, probably the far-distant horizon. The three are the steam engine, the steam turbine, and the Diesel engine. The newcomer is the much-discussed gas turbine.

The reciprocating steam engine, like many an oldtimer, came out of retirement to do its bit to help win the war, and it has performed distinguished service. However, for service on large vessels, the steam engine will not normally figure in the picture. Ship designers almost exclusively favor either steam-turbine or Diesel-engine power plants. There are, however, many steam-engine-driven ships. In fact, now more than half the world's tonnage is so powered.

The steam engine, which had ousted sail power, was in turn eclipsed for large vessels by the steam turbine soon after the turn of the century. This came about as a result of the development of the reduction gear under George Westinghouse's direction, which provided the means of coupling the inherently high-speed steam turbine to the slow-speed propeller. Like the dinosaurs, the steam engines simply grew too large to sur-

Until 1900 more than one-half of the merchant vessels built and registered in the United States were constructed of wood. Forty-two percent of these old ships were driven by sail power.

vive in present-day conditions. For large powers, they became gargantuan in size. Low-pressure cylinders, six feet in diameter, and five-foot stroke were not uncommon. The climax was reached in 1900 with a 40 000-hp engine with a low-pressure cylinder nearly ten feet in diameter and a six-foot stroke. Although the fuel economy of steam engines has been improved in recent years by use of superheated steam in the high-pressure cylinders and by the use of reheaters between cylinders, they still require half again as much fuel as a geared turbine. Also, a steam engine weighs more than a geared turbine and occupies more space; it encroaches on cargo space (i.e., revenue-producing space) more than can be tolerated. Furthermore, it is a reciprocating machine and is responsible for the vibration ills of such. All in all, except for its quick availability during emergency, the steam-engine's advantages of simplicity and ease of ship maneuverability are outweighed by its disadvantages.

The geared steam turbine continues to hold the number one spot as a ship drive. The variable-speed turbine running at speeds up to 6000 rpm is connected by a double-reduction gear to the propeller, which seldom turns at more than 120 rpm, and generally less than 100. To drive the vessel astern, a small turbine, usually with not more than one or two stages of bladings is built into the low-pressure turbine. The geared-turbine drive has no practical limit of size. Merchant cargo vessels, because of lower speed and smaller power requirement, seldom use turbines larger than 15 000 shp.

The geared turbine has an excellent record as a ship drive. It is efficient, thoroughly reliable and produces much less vibration than reciprocating prime movers. Modern double-reduction gears have an overall efficiency of about 98 percent and are remarkably quiet.

Turbine-electric drive has been applied to both naval ships and merchant vessels. A steam turbine drives an a-c generator, and the propeller is driven by a direct-connected synchronous electric motor.

The electric drive offers the utmost in flexibility, minimum vibration and noise. Its characteristics when maneuvering are excellent. Like the geared turbine, it has an excellent reliability record. It can deliver full power astern. Its overall efficiency is not as good as that of the geared turbine. Also, the geared turbine has a slight edge over turbine electric in weight and space required.

The Diesel engine has steadily grown in importance as a ship drive in the past dozen years. This has been particularly true since the appearance of the so-called, high-speed Diesel.

As a substantial aid to the American Merchant Marine in peace as well as in war is the establishment of a Merchant Marine Academy. Located at King's Point, Long Island, it will serve the merchant marine, as Annapolis serves the Navy and West Point the Army, by providing trained officers.

(High speeds for Diesels are about 600 to 750 rpm, instead of 100 to 300 which were common for many years.)

In terms of pounds of fuel per horsepower hour, the Diesel takes top honors among all classes of ship drives. In other words, a Diesel vessel may have a longer cruising radius on a given amount of fuel than a vessel with any other type of propulsion equipment.

The higher fuel economy of a high-speed Diesel drive does not always result in a net dollar economy because, although fewer pounds of fuel are required, the cost per pound is nearly double that of the fuels suitable for boiler furnaces. Only low-speed direct-connected Diesels are able to operate on the heavier, lower-cost fuel, although Diesel builders are working hard in this direction for the high-speed type and may succeed. Diesels require more lubricating oil, which is expensive, than do turbines. The Diesel has virtually no standby losses as does steam equipment, which advantage, obviously, assumes importance if stops are frequent.

Against the advantages of the Diesel must be weighed its shortcomings. It is usually heavier, bulkier, and more expensive in installed cost than a geared-turbine drive. Because of the greater number of moving parts, many of which are reciprocating, maintenance is greater. The Diesel also does not have the inherent overload capacity of the steam engine or turbine. The Diesel engine cannot escape the disadvantage that accrues from its reciprocating motion and its many moving parts. Inevitably, this engenders a higher order of vibration, lubrication, and maintenance problems than are entailed with rotating drives.

Tonnages in ship parlance have many meanings. It is not always even a unit of weight. *Deadweight* tonnage is the total weight, in tons of 2240 pounds, of cargo, fuel, water, store, passengers and crew required to load the vessel fully. *Displacement* tonnage, again in 2240-pound tons, is the weight of water displaced by the vessel and may be given as displacement light, i.e., without cargo, etc., or displacement loaded. *Gross* ton is a unit of space and is the entire internal cubic capacity of a ship in cubic feet divided by 100; i.e., one gross ton equals 100 cubic feet of ship space.

Diesel engines are connected to propellers in three ways; directly, through gears, and by electric motor. Of all three types of Diesel drive the large slow-speed unit which can be direct connected to the propeller has the greatest fuel economy. The largest of these built in the United States is the experimental 6000-shp engine for the Victory ship.

Gears permit higher engine speed, and allow two and sometimes four engines to be connected to a single shaft. The gear is rugged, simple. Only a single-reduction gear is required because the speed reduction is usually not more than three to one. Some form of torsionally flexible coupling between engine and gear pinion is required in order to spare the shock on the gear teeth of the engine-torque pulsations. These couplings, which are either hydraulic or electric, allow an engine to be quickly disconnected from the shaft in case of trouble. The geared drive, naturally, sacrifices some of the fuel economy of the direct-drive Diesel.

Diesel engines, like turbines, can be coupled to the propeller electrically. Such a drive has the same advantages of flexibility at a like cost in economy, weight, and bulk.

The gas turbine is as yet a stranger. Much discussed at present, the gas turbine has many theoretical advantages. However, these are at present of academic value only; the gas turbine, except for two or three land uses, is still a laboratory curiosity. Nevertheless, the Maritime Commission is actively studying the possibilities and has actually ordered the construction of an experimental 2500-shp gas-turbine power plant for installation in a coastal cargo vessel.

The gas turbine* does have appealing potential advantages. It is simple; in its basic form it consists of only an air compressor, liquid-fuel combustor, and turbine. It rotates at high speed, is extremely compact and light weight. With the simple, open-cycle gas turbine no water is needed, which means no boiler and condenser with their attendant pumps—a tremendous advantage in space and weight saving.

The main difficulty with the gas turbine has been low economy. Good efficiency can be obtained only by high temperatures, and by adding to it complicating features such as intercoolers, reheaters, etc. (which require water). The characteristics of the gas turbine at low speed are not good, and it cannot be reversed. The gas turbine with some form of connection to the propeller, however, is too attractive to be ruled out of the marine picture at this early stage of its development.

Cargo Handling

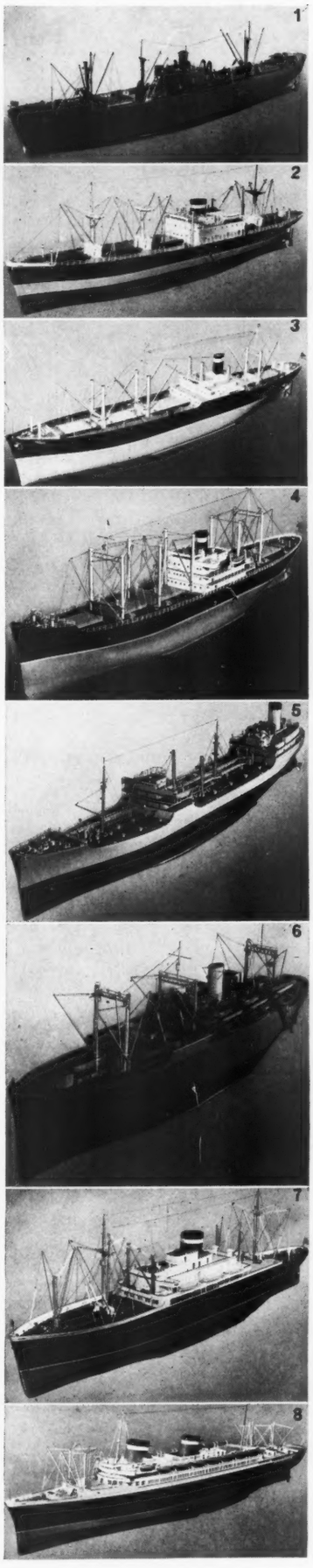
The merchant vessel's cargo-handling system, strangely enough, has more bearing on the cost of ship operation than has its propulsion equipment. Not many improvements can be expected in drive apparatus that bear to any large degree on overall ship-operation costs, especially with fuel comprising only 10 to 15 percent of the cost of ship operation.

The cost of cargo handling, on the other hand, is the largest single item of merchant-ship operation. It varies, of course, with the length of the route and other factors, but generally is not less than 30 percent of the total, is often 50 percent, and even may reach 70 percent of the entire operating expense of a merchant ship. This is made up of direct and indirect cargo charges, such as the actual labor of loading and unloading the freight, wages of the crew while in port, docking charges, etc. Anything that can be done to reduce the time in port looms large in the eyes of ship operators. This has spurred developments in cargo-handling machinery as well as better facilities at the docks. The electric-motor driven winch has now largely superseded the steam winch for reasons of efficiency, lesser deterioration of service with age, better operation in freezing weather, and instant availability.

Electric Power Supply

Merchant ships have large auxiliary electrical power plants to supply lighting, engine-room auxiliaries, radio, steering gear, refrigeration, air conditioning, fans, and even the cooking. But the greatest use of electricity has been to power the cargo-winch motors. These auxiliary power plants usually develop several hundred kilowatts. The electrical system, for example, on the Victory ship consists of two, 300-kw geared-turbine driven d-c generators, while for a C3 vessel three 300-kw electric plants are used.

*"The Gas-Turbine Combustion Cycle," *Westinghouse* ENGINEER, May, 1944, Page 78.



U. S. Maritime Commission photos of merchant vessels: 1—Liberty; 2—C1 cargo; 3—C2 cargo; 4—C3 cargo; 5—oil tanker; 6—C3 transport; 7—C3 cargo and passenger; 8—the S.S. America.

The Look Ahead

The record in building an enormous merchant fleet and the story of its war performance is one of which we can be proud. But now that the ships are built we cannot merely dust off our hands and sit back to admire our ocean fleet. The very size of the fleet brings problems of international responsibility. For some of the ships, especially the Libertys, it will be a matter of disposition; for the remainder it is one of effective utilization.

The entire merchant fleet is of concern to the American citizen. What, he may reasonably ask, is the future of the superliner? Or, with the enormous strides in aviation, do we need any sizable surface fleet at all? Catagorical answers are, of course, impossible. The day of the fast superliner, such as the Normandie, and the Queen Mary possibly is past. They were prestige vessels, whose economic justification was military.

Aircraft, undoubtedly, will carry a great amount of postwar tourist trade. How much no one knows, but ship operators and airline enthusiasts alike agree that a large proportion of the travel will still be by surface craft. Furthermore, more people will wish to travel, as a natural result of greater interest in distant places is an outgrowth of the global war. The more leisurely pace of the surface ship will continue to have much appeal to travelers.

As to bulk cargo, not even the most avid air enthusiasts foresee any major shift from vessel to aircraft. Numerous aviation authorities have predicted that within the next ten years the cost per ton mile for air freight might be reduced to six cents—yet this would still be approximately 60 times the cost to carry a ton of freight one mile by ocean-going ships. What is even more significant is that at present every cargo plane now in overseas operation requires more tankers to keep it in service than it replaces in freighters.

When peace comes, the American citizen can look with satisfaction upon a fine merchant fleet. But its continuance will be more than a matter of pride—one of national economic necessity and security.

CHARLES A. SCARLOTT

New Silicone Resin

The first electrical machine—60 years ago—depended on organic insulation. So do today's machines. Organic varnishes, although measurably improved, have not basically changed. The new silicone resins bring to insulation the much higher temperature limits of the silicon-oxygen chain as compared to the carbon-to-carbon chain. The new resins have been tried on many types of apparatus.

G. L. MOSES
Insulation Development Engineer, Transportation and Generator Div. Westinghouse Electric & Mfg. Co.

THE outputs of some electrical machines have been increased as much as one fourth by the increase in temperature limits, allowable with the new silicone-resin insulations. In other cases, the weight and bulk of rotating machines have been decreased by twenty percent. Temperatures generally, but by no means invariably, have determined machine ratings. Where this is true, the new silicone insulations, with their higher order of permissible temperature, will greatly increase the output from a given amount of working materials. The introduction of silicone-resins insulations is a major step forward in electrical apparatus.

Silicones Come in Many Forms

Silicone* is a generic name applied to a considerable group of semi-inorganic synthetic compounds that bridge the gap between the organic and inorganic materials. Several of these silicone compounds are resins physically resembling organic varnishes. Because the molecule of the silicone resin has an inorganic "backbone" (a silicon-oxygen chain), it has tremendously greater thermal stability than the best of the conventional organic resins. Many combinations of molecular structures are possible with these silicone materials, and they may be tailor-made to serve a variety of purposes. For example, they are available as insulating varnishes, insulating resins, lubricating greases, filling compounds, and fluids for various applications.

Silicone varnishes are available in forms quite similar to those widely used in the electrical industry. Numerous silicone varnishes are made with organic solvents, others are of the solventless type. Silicone varnishes are handled for impregnation and dip coating of insulation, coils and assembled apparatus by processes quite similar to those used for organic varnishes.

Silicone varnishes, in general, must be baked at temperatures far higher than those used for organic materials, usually 225 degrees to 275 degrees C. For this reason, it is essential that a minimum amount of the usual type of organic materials be subjected to these high baking temperatures. A composite insulation of silicone and organic materials is obviously worthless, for the organic insulation would be the weak link in the insulation chain.

To take full advantage of the heat stability of the silicone resins, both surface and sub-surface insulation must be thermally stable and moisture proof. A family of insulation materials comprising the combination of silicone resins with various inorganic base materials such as mica, glass, and asbestos has been developed paralleling the standard class B materials. These materials are listed in table I. High-temperature silicone insulation is being designated as HTS, as no standardized AIEE or NEMA insulation class is applicable.

For example, in the insulation of a typical traction motor, the coils are insulated with silicone-bonded glass-mica tape, a glass and mica wrapper, covered with a silicone-sized glass tape, and finally impregnated with silicone varnish. In the

*The new silicone resins here described resulted from the efforts of the chemists and engineers of the Dow Corning Corporation. As the developments progressed, they were checked against shop practice and in actual machines by Westinghouse engineers to the end that the silicone resins would be fitted to the specific requirements of the electrical industry. Among the Westinghouse engineers who contributed to this activity were: J. DeKiep, J. G. Ford, L. R. Hill, R. F. Horrell and R. H. Runk.

After 2966 hours of operation at an estimated hot-spot temperature of 250 degrees C, the HTS insulation on this 250-kva, 440-volt generator was still in satisfactory and usable condition.

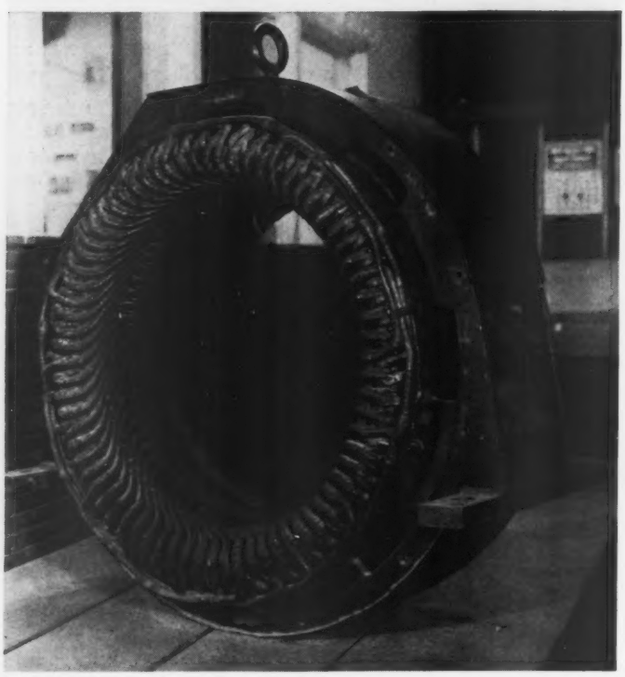


TABLE I—AVAILABLE FORMS OF SILICONE-RESIN INSULATION

Form	Size	Use
Silicone-Varnished Glass Cloth	Continuous rolls 18" wide. Two thicknesses 0.004" and 0.017"	Backing for composite insulation
Silicone-Glass-Mica Wrapper	Sheets 18" by 36". Two thicknesses — 0.008" and 0.010"	Coil Wrapping
Silicone-Glass-Mica Wrapper	Sheets 18" by 36" by 0.015"	Phase insulation in stators
Silicone-Varnished Glass-Covered Wire	All standard sizes	Magnet and stator winding
Silicone Filling Cement		Plastic filling cement —not rigid
Silicone-Bonded Glass-Mica Tape	All standard widths. Two thicknesses— 0.055" and 0.0075"	Ground insulation for coils
Silicone-Sized Glass Tape	Widths up to 1". Thicknesses up to 0.015"	Protective outer wrapping for coils
Silicone-Sized Asbestos Cloth	Sheets 36" by 36" by 0.035"	Cushioning material

Boost Insulation Temperature Limits

case of a small induction motor, additional members of the silicone family of materials play an important part. The stator is wound with silicone-treated, glass-covered magnet wire. The coils are insulated from the core and between phases by mica and glass slot cells, silicone bonded. The stator is then impregnated and finally dipped in a high-temperature silicone varnish to furnish the waterproof external coating.

Results of Tests on Silicone

Comparing glass cloth varnished with silicone as against that coated with a standard class B varnish, the superior heat stability of silicone materials is clearly evident. After 24 hours at 205 degrees C, the sample of silicone material retains its original flexibility. One the other hand, after two hours, the class B material is severely darkened and embrittled with attendant loss of desirable electrical properties. Interesting quantitative measurements of the behavior of silicone films on aging are shown in Fig. 1.

In the range from 200 to 250 degrees C, the silicone resins roughly follow the classical "ten degree rule," that is, the life is doubled for each drop of ten degrees in temperature. This is illustrated in table II.

Water has little effect on silicone-resin insulation. Dried but unaged silicone films have the same resistance to the passage of water as the better water-proofing insulating varnishes or soft vulcanized rubber. However, after aging one month at 200 degrees C, the organic films show erratic and extremely high permeability whereas the silicone film actually improves slightly with aging at this temperature. Data collected on coils in service confirm these results.

Certain low-viscosity silicone fluids of the lubricant type have achieved much publicity as water repellents. Water does not form a continuous film on surfaces treated with these fluids. Many interesting and useful non-electrical applications of this property should result. Paper raincoats, silicone impregnated, have been mentioned by one writer. Fishermen hail the fluids as unequaled for floating dry flies in fast water.

Tests Results on Coils

Coils subjected to accelerated thermal aging tests invariably demonstrate that HTS insulating materials have a tremendous advantage over conventional class B insulation in thermal endurance. In one test, severe vibration and thermal cycling were combined to check the endurance of various types of insulation. A d-c motor armature was vibrated severely during thermal cycling, obtained by applying 75 amperes 72 times per minute from a 420-volt a-c supply. This load was held for three minutes and the tests were continued for 36 days, 16 hours per day. Temperatures of about 230 degrees C were observed. Coils tested included ones insulated with mica tape, glass and asbestos wire covering with various types of mica wrapper, and glass and asbestos finishing tape. One of the four groups was HTS-insulated (glass-covered wire, glass and mica wrapper, glass tape with silicone resin treatment throughout). The HTS-insulated coils satisfactorily withstood this rigorous test and upon its completion, the condition of this insulation was by far the best of any tested. Not all coils insulated with class B insulation had failed at the end of this period, but the insulation showed signs of thermal aging and embrittlement of the resins, whereas the HTS coils were about as good as new.

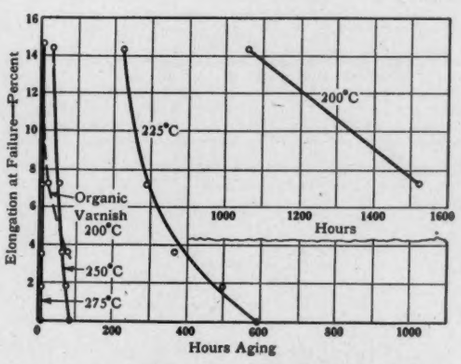


Fig. 1—Comparison of the elongation of silicone films and organic varnish films (each 0.002 in. thick) after thermal aging.

Temperature Limits Suggested by Tests

Based on the equivalent life of class B insulation, there is an indication that the limit of permissible temperature will be considerably in excess of present class B temperature limits. The development work on silicones is progressing rapidly and it is not possible to establish definite temperature limits for these materials at the present time since their quality is being steadily improved and higher temperature limits may result. Temperature limits of at least 175 degrees C with a good margin of safety may be expected for these materials, with perhaps further increase later.

Bearing failure rather than insulation deterioration ended the 3376-hour test of this motor operating at 250 degrees C hot-spot temperature. Even molten metal caused little insulation damage.

Despite the difference in size, these two motors each produce 10 hp at 1750 rpm. The smaller has HTS insulation and weighs 210 pounds, the larger has class A insulation, weighs 410 pounds.

Improved thermal endurance can be utilized in three important ways by the designers of electrical equipment.

1—To reduce the size and weight of electrical equipment where operating temperature can be increased and where no reduction in insulation life can be tolerated.

2—To increase greatly the service life of insulation where conventional size, weight, and temperatures are maintained.

3—To permit operation in ambient temperatures materially above limits permissible for usual types of insulation.

Some Uses Peculiarly Applicable to Silicones

All the uses to which silicone resins and HTS insulation have been put cannot be described at present. However, the following are a few typical examples of their uses.

Totally Enclosed Fan-Cooled Induction Motors

Early in 1942 a totally enclosed fan-cooled induction motor was wound for 10 hp using the best available class B insulating materials and treated with silicone resin varnish. With class A insulation the rating would have been three hp and with class B, five hp. Tests included full-load temperature run, overload run for 13 hours at 300 degrees C total operating temperature and peak overload test during which 500 degrees C total temperature on the winding was observed by thermocouple. These tests were followed by an accelerated life test on the insulation during which the motor winding was operated at 210 degrees C rise by resistance (250 degrees C hot-spot temperature) for 3376 hours (140 days). The motor was dismantled and examined periodically and the winding was subjected to a high humidity test. The test was ended by a bearing failure resulting in damage to the winding. The heat accompanying the failure caused molten aluminum to run over the winding with surprisingly little damage to the silicone-resin insulation.

A second motor with the same insulation as the previous one, rated at 25 hp (15 hp with class B), 1750 rpm ran under load for over 3200 hours at 250 degrees C total hot-spot temperature before a bearing failure stopped the test.

Auxiliary Generators

One 250-kva, 440-volt generator made with HTS insulation throughout the stator was given a preliminary temperature test with the stator short-circuited at 2¾ times normal current. This resulted in an observed stator-winding temperature of 355 degrees C for six hours. Subsequently, the stator was redipped and baked and placed on an accelerated thermal-aging test in which it was heated on alternate days to obtain thermal cycling. The observed rise by resistance on the stator winding was 210 degrees C, resulting in an estimated hot-spot temperature of 250 degrees C. After 2966 hours, the insulation was still in satisfactory and usable condition. The winding was then subjected to a severe humidity test, with subsequent high-potential and running tests, followed by short circuit at full voltage. Finally, the winding was tested—without being dried out—at high potential to breakdown. Failure occurred at 1600 volts.

Magnet Coils for Relays and Contactors

Several hundred HTS-insulated magnet coils of various types are in operation on street-railway controls. Experience with these coils indicates a life considerably better than that of usual coils with class B insulation. One laboratory test of magnet coils has been in operation over 5000 hours at an observed temperature of 235 degrees (250 degrees C hot spot).

The Significance of Silicone-Resin Insulation

To evaluate the advantages to be derived from the increased operating temperature possible with HTS insulation, specific examples must be considered. The following study is based on increasing temperature only, maintaining speeds and conventional insulation allowances.

Higher temperature operation may introduce other problems, particularly mechanical ones, such as lubrication of bearings and expansion during thermal cycling. Increased temperature may also have an effect on efficiency and, in some cases, on power factor. Sometimes high efficiency is preferred to low weight or cost and no gain may be possible. This, too, requires individual consideration and evaluation for each application. The primary purpose of this review is

TABLE II—FAILURE TIME (HOURS) OF SILICONE INSULATIONS

Aging Temperature Degrees C	14.4% Elongation	7.2% Elongation	3.6% Elongation	1.8% Elongation	Craze Failure Time
250	36	55	63	80	85
225*	225	290	375	500	590
225**	205	314	360	456	485
200*	1060	1630	...	...	...
200**	1160	1790	...	...	...

*Actual **Calculated by 10-degree rule

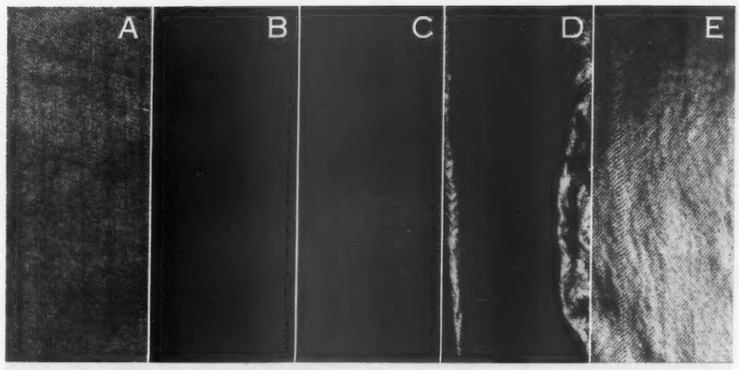
TABLE III—WEIGHT REDUCTION OF INDUCTION MOTOR BY INCREASE IN OPERATING TEMPERATURE

Totally Enclosed Fan-Cooled Induction Motors									
	2 Hp			15 Hp			40 Hp		
	Insulation			Insulation			Insulation		
	A	B	HTS	A	B	HTS	A	B	HTS
Percent Total Wt.	100%	79.5%	63%	100%	81%	53%	100%	69.5%	54%
Power-factor	82%	81.5%	79.5%	84.4%	84.3%	84.1%	87%	86%	86%
Temperature Rise	40°C	63°C	113°C	43°C	65°C	125°C	44°C	64°C	106°C

to point out the possibilities for reduction in weight and size through increased temperature limits on certain designs.

For example, the output of a traction motor can be increased by simply adding more load on an existing design, as shown in Fig. 2. Additional advantage could be obtained through redesign.

As is generally true in engineering with the introduction of a new material, the fullest advantage can be taken of it, not when it is simply used as a substitute but when the design is made to include it.



Comparison of silicone varnish and high grade organic varnish on glass cloth under the following conditions: (a) silicone unaged, (b) organic unaged, (c) silicone aged 2 hours at 250 degrees C, (d) organic aged 2 hours at 250 degrees C. Sample (e) shows the silicone-treated glass cloth in good condition at the end of 20 hours at 250 degrees C whereas the organic varnish deteriorated and was badly damaged after but 2 hours.

Large Direct-Current Apparatus

The effect of temperature on the size and rating of large d-c apparatus depends upon the design characteristics, particularly on the ratio of copper loss to iron loss. The design of this class of apparatus is standardized through the establishment of a coordinated family of frame sizes for the various motor ratings which must satisfy widely different conditions. This naturally results in a larger and heavier machine for a particular application than one designed specifically for the job. The weight reduction possible from such redesign has been omitted from this study, the sole variable being temperature. The saving in weight of a 1200-kw, 720-rpm, 600-volt machine, using class B, 60-degree rise insulation instead of class A, 40-degree rise insulation, is 15 percent. With silicone insulation, 80 degrees rise, the saving is 25 percent. For a slow-speed machine, 60 rpm, 2250 hp, the corresponding savings are: class B, 12.5 percent; silicone, 20.5 percent. In this case, only 20 degrees C temperature advantage was taken from the HTS insulation above class B (based on 50 degrees C ambient).

Large Synchronous and Induction Motors

Basically, many of the small and low-speed machines cannot be made smaller than at present through increase of operating temperature above class A limits (40 degrees C rise by thermometer) because of efficiency requirements. The larger machines and higher speed machines (eight poles or less) could in most cases be reduced in weight approximately 20 percent by taking advantage of present class B temperature limits (60 degrees C rise by thermometer). In addition, probably 25 percent of these larger or higher speed designs could be made still smaller (10 percent to 20 percent) if an increase of 40 degrees C were possible above the present temperature limitations governing class B insulations.

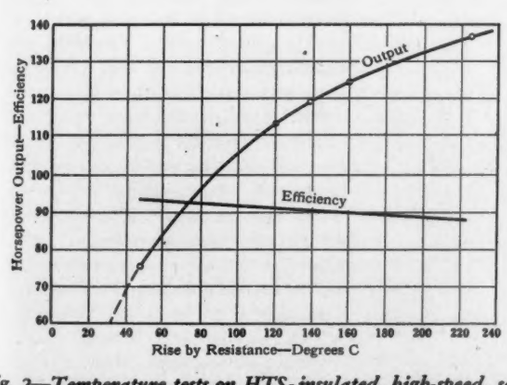


Fig. 2—Temperature tests on HTS-insulated, high-speed, self-ventilated traction motor show an increase in output obtainable at higher operating temperatures with constant speed.

Traction Motors

Present standards for traction apparatus allow 120 degrees C rise (by resistance) on the rotor and 130-degree C rise on the stator. These temperatures are sufficiently high that gains from increase in operating temperature are rapidly diminishing. Based on a modern 600-hp traction motor, a 40-degree C increase in armature and field rise results in about 20 percent increase in rated output. For the same rating and the 40-degree C increased rise, a new machine would weigh about 85 percent as much as a standard class B insulated machine.

Small Induction Motors

Most small induction motors are class A, 40-degree C rise machines. Some weight reduction would be possible on certain designs, in going to 50-degree C rise without change in insulation. Further weight reduction would be possible on some by using conventional class B insulation. On some motors, such as the open and splash-proof types, the torques, efficiency, and power-factor requirements limit the advantages gained through the high-temperature insulation. On the other hand, the totally enclosed fan-cooled motor is particularly suited to such redesign for weight reduction because the operating temperature as the limiting factor has been increased. Several of the examples given in the foregoing illustrate this. The data in table III indicates the possibilities for weight reduction by increase in operating temperature.

Future Possibilities and Limitations

The trend to higher operating temperatures was stimulated by the advent of fibrous-glass insulation. However, because it was still necessary to use organic varnishes with these glass insulations, full use of these higher temperature characteristics was impossible. If silicone resins fulfill the promises of test results, extensive use of high-temperature silicone insulation can be expected. Many types of electrical machines are larger and heavier than need be if HTS insulation can be used. Such designs should be reviewed and re-evaluated where HTS insulations can be utilized economically. These new materials must not be considered as panaceas for all insulating problems but should be applied with caution and vision on specific applications where their use can be justified. Unquestionably the new silicone resins constitute one of the greatest advances made in electrical insulations.

Fatigue Testing at Elevated Temperatures

THE many new high-temperature alloys, developed under pressure of war needs, open new vistas to the machine designer. But just what is the endurance of these metals at elevated temperatures? In the past, the endurance limit of alloys at the proposed operating temperature has been estimated from room-temperature tests. In the Mechanics Division of the Westinghouse Research Laboratories is a battery of fatigue-testing machines that determine the endurance limit of metals at temperatures as high as 1500 degrees F.

Conventional room-temperature fatigue testing is in itself a time-consuming operation. A complete endurance determination involves testing from five to twenty specimens, some of these tests requiring several weeks. Usually these tests do not exceed ten million cycles alternate reversals of bending stress because the conventional stress-cycle curve becomes almost straight and horizontal at that number of cycles of stress, indicating that an endurance limit has been reached.

If now we add the additional parameter of temperature to the tests, the time consumed with the usual fatigue-testing equipment is lengthened enormously. One of the principal reasons for this is the fact that at elevated temperatures the characteristic stress-cycle curve does not flatten at ten million cycles as at room temperature. In fact, the curve is still falling at the end of 300 million cycles. Tests as high as a billion cycles are run in order to carry the test curve out to a point where a truer characteristic is secured.

A high-temperature fatigue-test machine must provide constant temperature for the test from room temperature to 1500 degrees F. It must also be able to stress the specimens at a rate not less than 100 cycles per second (but not so great as to affect markedly the endurance limit) so that the time required for the test will not be inordinately long. The specimens should be simple in form. Complicated specimen clamping devices must be avoided because of the high relaxation rates encountered at the elevated temperatures used in the tests.

The six machines in use at the Research Laboratory at East Pittsburgh for the past three years stress the specimens at a frequency of 120 cycles per second. Two stator coils connected to a two-phase 60-cycle supply line vibrate a driving mechanism which stresses the specimen at this frequency. The amplitude is controlled by a make- and break-contact in the input circuit. The entire system is mechanically tuned to resonance at this frequency to minimize the driving force necessary to flex the specimen.

The specimen is kept at the desired temperature by a bell-type furnace with a differential expansion relay. The temperature of the mid-point of the specimen is continuously measured by a thermocouple inserted in an axial hole in the specimen. The amplitude of the vibrations is controlled by a moving contact. It is set by observing a target on the vibrating armature through a calibrated microscope. This target is a gold bead and when the machine is in operation, the rapidly vibrating armature causes the bead to travel back and forth so that it appears in the viewer as a solid line. The length of this apparent line is adjusted to the double amplitude desired by matching it with the calibrations visible in the microscope viewer.

This machine thus makes endurance tests of specimens at any temperature up to 1500 degrees F and runs the number of cycles of the test up to some 300 million in a month. Upon failure of the specimen, there is a reduction in stiffness due to the crack. As the crack progresses, the system is detuned to such an extent that the amplitude is reduced and the control contacts cease to strike. The test is then automatically stopped electronically.

The amplitude of the 120-cycle-per-second bending stress is checked by Mr. P. R. Toolin.

Heat-Shock Testing

MANY industrial operations subject metal parts to severe and repetitive heat shocks. The development of an alloy peculiarly applicable to a specific usage entails long, drawn-out tests if the alloy is tried in the relatively long duty cycle of the machine itself. The making of duplicate parts from various alloys to fit the machine costs time and money. Dr. Frederick C. Hull of the Westinghouse Research Laboratories uses a resistance welder to make an accelerated heat-shock test on alloy samples of simple shape.

The test piece is simply a short rod, three-eighths of an inch in diameter and two inches long. The test piece is machined to a smooth surface comparable to that of the machine part for which the alloy is intended. The sample is held between the water-cooled copper electrodes of a resistance welder with a force of 300 pounds. The large current from the welder, which may be up to 4500 amperes, flowing through the piece, supplies energy to heat it to any desired temperature up to the melting point.

There are two controls on this heat-shock testing device. One governs the quenching and heating cycles. The other, a standard electronic resistance-welding unit, limits the current delivered by the welder and is thus a heat control.

The heating and quenching control is a series of revolving drums with metal segments in the surface that engage contacts and, in completing the circuit, operate relays in proper sequence. In the heating cycle, the welder is energized and a series of pulses of current is passed through the test piece for about five seconds. This brings the specimen up to desired temperature. This is followed by five seconds of current pulses that are more widely spaced, which maintain the temperature level attained in the first series of more closely spaced pulses. The welder is then de-energized and the test piece sprayed with water for the quenching operation.

The heat control is a standard electronic control for regulating the current to a resistance weld. By means of a thyratron, any portion of the current wave can be used. For relatively low temperatures, a thermocouple and potentiometer are used and for elevated temperatures, an optical pyrometer is used to establish and check the temperature at which the test piece is to be used.

One possible application envisioned is to use this scheme to test forged or rolled bars for cracks. Minute surface cracks, otherwise invisible, become readily apparent after from 15 to 25 cycles of heat

Dr. F. C. Hull observes the cooling cycle of the heat-shock test.

shock. It is thought that heat-shock tests may be of considerable aid in developing alloys for automatic molding-machine dies. There are, of course, many other variables involved, such as surface erosion caused by action of the metal or material being molded, abrasive action of molded material, etc. These factors all must be integrated with the resistance of the material to thermal-fatigue failure—which can be determined with this simple, available, easily controlled heat-shock testing equipment—to get a true picture.

New Developments in Paper-Capacitor Impregnants

WORLD-WIDE usage of equipment by our armed forces has disclosed many weaknesses in d-c impregnated-paper capacitors which now have been largely corrected. Problems once considered academic and of interest only to research people suddenly have assumed intense practicality. Such a problem is the loss of capacitance (as much as 25 or more percent) by impregnated-paper capacitors at low temperatures as is also the shortened life at elevated temperatures. The answers to these two problems by Dr. L. J. Berberich and his associates have resulted in capacitors which perform with increased efficiency and longer life whether in the withering heat of the tropics or the intense cold of the stratosphere.

Direct-current impregnated-paper capacitors are used in filter circuits, tuned audio-frequency circuits, and circuits requiring blocking and by-passing elements. Any great deviation from the rated capacitance, particularly in tuned circuits, is important. Also, in many applications, these capacitors are subjected to d-c voltages accompanied by not inconsiderable a-c voltages. Thus, the a-c as well as the d-c characteristics of the capacitor are of considerable importance.

This type of capacitor is impregnated with a chlorinated liquid which is a polar substance. That is, a molecule of the liquid can be visualized as being dumb-bell shaped with a positive charge at one end and a negative charge at the other end. When a voltage is impressed across the capacitor, the molecules align themselves by rotation to present the negative end to the positive side of the applied voltage and the positive end to the negative side. Reversing the voltage polarity causes the molecule to rotate 180 degrees to reverse its polarity to correspond to the new conditions. Obviously, when an a-c voltage is imposed, this reversal takes place according to the frequency of the applied voltage.

As this is a physical action by a discrete particle, any marked increase in viscosity, such as caused by cooling, tends to retard the molecules during this reversal, particularly at the higher frequencies. At extremely low temperatures, this ability to reverse freely is largely lost. Because polar materials depend on the rotation of the molecules for part of the dielectric constant, under conditions of low temperature only part of the rated capacitance is effective.

A new chlorinated liquid composition has been developed which maintains its dielectric constant to considerably lower temperatures than is the case with the widely used chlorinated diphenyl impregnant. This special Inerteen has physical and electrical characteristics quite comparable to standard Inerteen capacitor fluid except that it has considerably lower viscosity and freezing point. This change in character makes possible unrestricted rotation of the dipoles at 60 cycles down to about —40 degrees C, whereas the dielectric constant (a measure of dipole rotation) of standard Inerteen falls off sharply at about —5 degrees C. The practical value lies in the fact that the capacitance of capacitors impregnated with standard Inerteen (rated at 60 cycles and 25 degrees C) falls off sharply at about zero degrees C, and at —40 degrees C is but 70 percent of rated capacitance. Impregnated with special Inerteen, the capacitance at 60 cycles does not begin to drop below the rated figure until after —35 degrees C and at —40 degrees is still 95 percent of rated capacitance. At the higher frequencies, the gain in capacitance at low temperatures through the use of the new liquid is somewhat less, but is still appreciable at even a megacycle. However, paper capacitors are not particularly suited for application in circuits involving such high frequencies, because of the inherent high dielectric loss in the paper at these frequencies regardless of the impregnant employed.

Special impregnating mineral oil preserves a practically flat dielectric-constant curve (effective capacitance) from 85 degrees C to —70 degrees C at 60 cycles and at one megacycle is still 86 percent of rated capacity at —40 degrees C. However, the special Inerteen has an inherently high dielectric constant and to be comparable, the oil-filled capacitor needs to be half again as large.

Chlorinated hydrocarbon fluids have excellent electrical characteristics for impregnated paper-capacitor use. However, under sustained d-c voltage, evidence indicates that molecules of hydrogen chloride are split off, which attack the capacitor foil to form aluminum chloride. This, in turn, catalyzes further decomposition of the impregnant and perhaps even the paper. Life under a-c stress is considerably longer than under d-c stress and some electrolysis phenomena undoubtedly takes place. Chemical compounds to prolong the life of the capacitor have been developed and are called stabilizers. The effectiveness of the new stabilizer, when added to either the standard or new Inerteen, is shown by an accelerated life test. The average life without stabilization is 120 hours at 85 degrees C and 1000 volts per mil, using the special Inerteen. With the stabilizer added, the capacitor still had not failed at 3000 hours.

Test capacitors are placed in the special impregnating vessel by Dr. L. J. Berberich.

Three-kilowatt mercury lamps provide the 50 footcandles of illumination needed for the difficult task of conditioning and inspecting steel slabs.

Lighting with 3000-W

A new mercury-light source provides from one tube as much
sumes only half as much energy. It is now being used for ill
of the mercury-lamp family, it provides seven and a half time
60 times as much as the 40-watt fluorescent lamp, which ha

WILLIAM H. K

Lighting Eng
Westinghouse Elec.

A LIGHT source as intense and concentrated as a three-kilowatt mercury lamp—virtually a miniature sun—might seem to have little application for general lighting. However, in the two years it has been available, it has been the answer to a number of difficult lighting problems. It is, however, a specialized source requiring careful application to obtain satisfactory visual, electrical, and mechanical results.

Characteristics of the New Light Source

The essential electrical and mechanical data on this source is given in table I. The major advantages of the 3-kw mercury lamp are: its extremely high light output, long life, and high efficiency. Producing 120 000 lumens, 40 lumens per watt, the light output is about six times that of the 1000-watt incandescent lamp (21 lumens per watt) and 57 times that of a 40-watt fluorescent lamp. The efficiency of the mercury-vapor lamp is twice that of the incandescent source and is exceeded only by that of the fluorescent lamp.

The high light output means that relatively few luminaires are required to produce high illumination levels. This results in lower installation cost and reduced maintenance, while the long life reduces the replacement costs. Considering these points and the lamp's high efficiency, the 3-kw lamp produces light cheaper than any other general lighting lamp in extensive use today.

The extreme brightness of the 3-kw mercury lamp is at once a virtue and a potential weakness. This attribute must be given careful consideration in applying the lamp. For direct lighting, 3-kw luminaires should not be installed lower than 40 feet from the working level. Reflectors must properly shield the lamp in the normal field of view and must be located to prevent direct viewing of the light source. If the work in the lighted area has to do with large polished surfaces such as aluminum sheets, 3-kw direct lighting will cause severe reflected glare. However, indirect lighting, using 3-kw mercury lamps, offers real possibilities for work on specular materials.

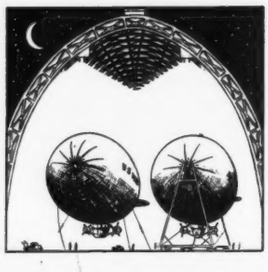
The color of light is the characteristic yellow-green of mercury lighting. This has not been found objectionable in the metal-working industry. However, colored objects and complexions present an unnatural appearance in light from a mercury-vapor source.

The operation of gaseous sources is adversely affected by low ambient temperature. At a low temperature, the mercury vapor attempts to condense or "freeze out." With the 3-kw lamp the combination of mercury and argon is such that the voltage required for starting is appreciably higher at the lower temperatures. Therefore, some lamps may not start if the ambient temperature is below freezing. However, once the lamp has reached normal operating conditions, it will remain lighted at temperatures considerably below 32 degrees F because of the heat produced within the lamp.

Some Typical Applications

With these advantages and limitations in mind, engineers have found several applications ideal for this new source. For each application optimum seeing conditions have been furnished with relatively few lighting units.

Foundry—In foundries, general illumination of the order of 30 footcandles has been found necessary to increase production and reduce rejects. Here workers are generally looking toward the floor and high brightness from overhead is not annoying. Also, the materials handled have dull finish and specular reflections are not encountered. Under these conditions, 3-kw mercury lighting is excellent for foundries in which a mounting height of 40 feet or more can be attained. The desired 30 footcandles or more can be obtained with luminaires installed on spacings of approximately 35 feet.



Steel-Mill Inspection and Chipping—The chipping, slab conditioning, and inspection operation in a steel mill re-

)-Watt Mercury Lamps

e as much light as six 1000-watt incandescent lamps, but con-ed for illumination of large areas with high ceilings. Newest half times as much light as the 400-watt mercury lamp and which have previously been used for industrial installations.

IAM H. KAHLER

hting Engineer
use Elec. & Mfg. Co.

quires illumination of 50 footcandles and more. To obtain this high level with conventional lower wattage equipment such as 1000-watt incandescent lamps means close spacing of luminaires and high maintenance cost. By using direct 3-kw mercury luminaires, 50 footcandles can be supplied from mounting heights of 40 and 50 feet with luminaires spaced 20 by 30 feet.

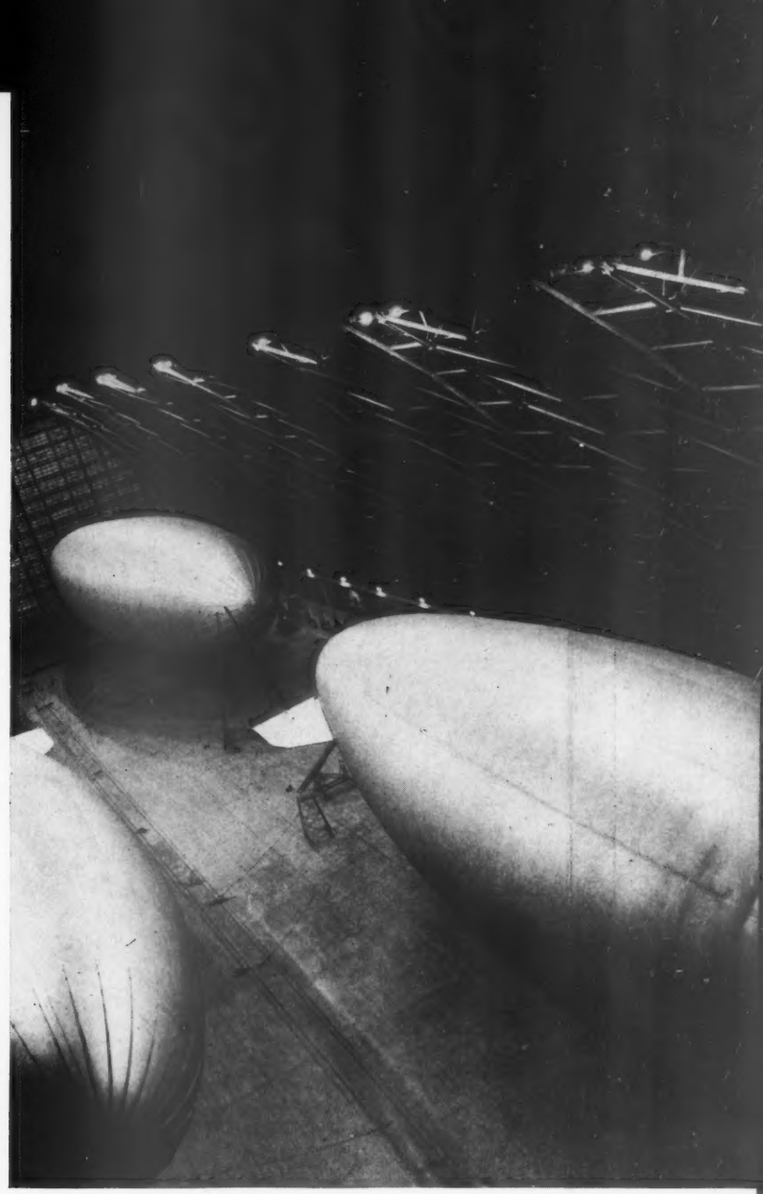
Blimp Hangars—A most spectacular use for 3-kw mercury lamps has been for the illumination of Navy blimp hangars. These are tremendous structures with floor area equal to three football playing fields, and with high ceilings. A typical hangar is 1000 feet deep, 30 feet wide, and 175 feet high. They are constructed of fire-resisting timber and are entirely windowless, except for huge doors at either end. The original lighting specifications called for 150 high-bay reflectors with 1500-watt incandescent lamps scattered over the entire ceiling of the structure. This method required thousands of feet of copper wire. The maintenance of such a large number of lamps threatened to be a serious problem.

Forty-two of the 3-kw mercury units were used to do the same job as the 150 incandescent units. These 42 lamps were mounted along two catwalks, 133 feet above the floor of the hangar, which permits servicing the lamps and their fixtures. The power consumed by the mercury installation is 133 kw, as against 225 for the incandescent lighting system. Furthermore, the 3-kw lighting equipment is most economical when supplied by a 460-volt primary circuit. At this high distribution voltage, the copper in the distribution system is but a few pounds. Low cost, simplicity, saving of critical materials, and easy maintenance are all achieved in applying 3-kw mercury lighting to blimp hangars.

Paint Shops—In a large paint shop in an aircraft plant, the 3-kw lamp was used to furnish a high level of lighting with a minimum of maintenance expense. Lamps and reflectors were mounted above the ceiling over flush glass ceiling panels and afforded high-intensity, diffused light.

Indirect industrial lighting—Indirect illumination has always been the lighting engineer's dream for applications where polished metal such as aluminum, tin plate, or stainless steel is handled and fabricated. This large high-brightness light source makes this form of lighting practical where industrial conditions permit the maintenance of a white ceiling.

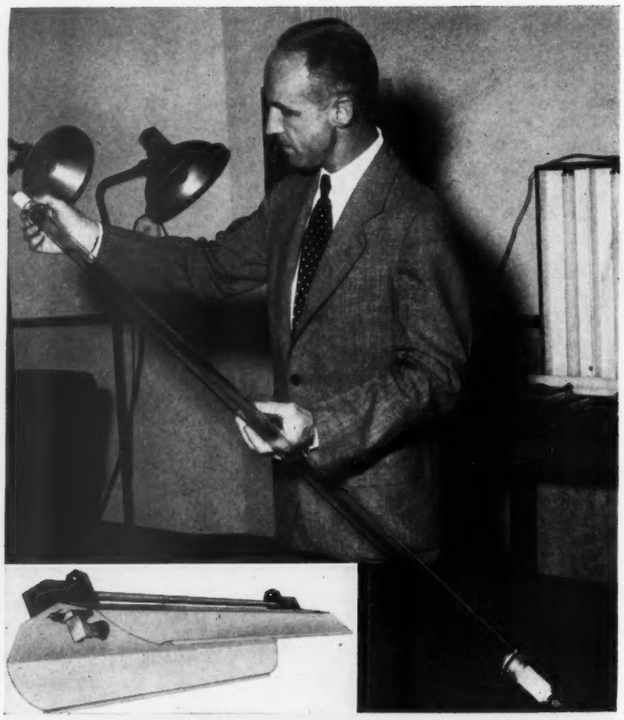
Most 3-kw installations have required direct lighting luminaires. The design of the equipment involved several mechanical problems because the lamp presents a tremendous concentration of light and heat (3000 watts). Essentially, the luminaires consist of a reflector, a wire channel, and two lamp holders. The reflector must be deep to shield the high brightness of the source. It is impossible to use reflectors of non-critical materials as was done with fluorescent equipment, because high lamp temperature demands a fire-resisting reflector material. Therefore, porcelain-enameled steel is used. The type of wire channels used on fluorescent luminaires could not be used as the high temperatures developed would destroy any available wire insulation. A ventilated channel is built to allow free air circulation around the entire conductor enclosure. Even with the ventilating feature, high-temperature cables must be used for wiring luminaires for the 3-kw mercury lamps.



Three-kilowatt mercury lamps, mounted 133 feet above the floor furnish approximately seven footcandles of illumination in this hangar.—U. S. Navy Photo.

At each end of the lamp is a single spade-shaped contact terminal. The lamp holder at each end of the wire channel is slotted to take the spade terminal. After the lamp is inserted, it is rotated 90 degrees and held securely by spring contacts. Because the open-circuit voltage across the lamp holders is 850 volts, it was considered hazardous to remove a lamp with the power on. Therefore, as a safety precaution, the lamp holders contain an automatic switch. When the lamp is inserted, the holding contacts are not energized until the lamp has been rotated 90 degrees in the socket.

The 3-kw mercury lamps provide safe levels of illumination by revealing clearly all obstacles on the deck.—U. S. Navy Photo.



The relative size of the three-kilowatt mercury lamp is shown by comparison with the fluorescent and smaller mercury lamps in the background. The insert shows the luminaire construction.

Heretofore, mercury lamps have been available in ratings of 100, 250, and 400 watts. These are relatively short tubular bulbs with an electrode in each end and with a conventional screw base at one end. Unlike these, the 3-kw lamp, which is four times longer than the 400-watt mercury lamp, is a slender tubular bulb with a single contact terminal at each end.

In mercury lamps light is produced by passing an electric current through a gaseous mercury vapor. The mercury lamp contains a small amount of argon gas and a drop of mercury. When sufficient voltage is applied to the electrodes at each end of the lamp, the argon molecules and mercury vapor become ionized, that is, the particles of gas become carriers of electricity. This ionization process converts electrical energy into light and heat. Thus, a visible arc is established between the two electrodes. This starting arc is low in intensity, but the heat of the arc vaporizes more and more of the mercury until a stable operating condition is reached. Because this warming-up process takes several minutes, mercury lamps do not light immediately to full intensity.

TABLE I—COMPARISON OF 3-KW LAMP WITH OTHER LIGHT SOURCES

Type of lamp	Mercury	Mercury	Fluorescent	Incandescent	Incandescent
Wattage	3000	400	40	100	1000
Overall length—inches	54⅞	13	48	5⅝	13½
Rated life—hours	2000	3000	2500	750	1000
Special operating auxiliary required	Yes	Yes	Yes	No	No
Lamp-starting voltage to be supplied by auxiliary	850	220	200	.....	.....
Lamp operating voltage	540	135	108	Depends on lamp voltage rating	
Lamp operating current	6.1	3.0	0.41	Depends on lamp voltage rating	
Available for what line voltages	220 to 240, 440 to 480	100 to 125, 200 to 250	110 to 125, 199 to 216, 220 to 250	115, 120, 125, 230, 250	115, 120, 125, 230, 250
Light output—lumens	120 000	16 000	2100	1600	21 000
Relative number of lamps required for equal light output	1.0	7.5	57.0	75.0	5.7
Color of light	Strong yellow-green	Strong yellow-green	White	Mild yellow-orange	Mild yellow-orange
Lamp efficiency—lumens/watt	40	40	52	16	21
Brightness	Extremely high	High	Low	High	Very high

Starting and Current Limitation

Like all gaseous light sources, the 3-kw lamp must be operated from a high-reactance transformer unit. This is essential to provide proper starting voltage, and to limit the lamp current during operation. Both single- and two-lamp transformers are available for 230- or 460-volt distribution circuits. They are power-factor corrected to minimize line loading. The 3-kw transformers are all two-wire, single-phase units. Therefore, when connected to three-phase power feeders, they are staggered on the phases to balance the load.

Because 3-kw mercury lighting can be connected to either 230- or 460-volt lines, the system is usually connected directly to power feeders. Thus, step-down transformers can usually be eliminated for 3-kw lighting.

In most installations, the 3-kw mercury lamps are supplied from 460-volt distribution systems to save critical copper and installation cost.

Mercury Lighting in the Future

Mercury lamps may never be a universal light source because of their color. In many applications, however, mercury lighting provides the optimum in desired effect. Beautiful outdoor effects can be obtained because the yellow-green light emphasizes the green of lawns and foliage. The New York and Chicago World's Fairs employed mercury lamps to create spectacular displays otherwise unobtainable.

There is considerable interest in mercury lighting for postwar street lighting. For many applications it is considered superior to sodium-vapor lamps.

Modern Equipment Aids System Savings

There is no rest for the weary—or the electric-power industry. Although it has just turned in an astonishing record of supplying war-industry loads, it is faced with several hard facts. Power-production costs are rising; revenue per kwhr will, if anything, decline; service quality must not be allowed to deteriorate. Economies must be effected. The distribution component of the power system, in which resides six out of ten of the investment dollars, seems the most likely field for savings. Cashing in on the greater reliability of today's distribution apparatus and adopting simplified substation arrangements appear to be the most attractive methods of effecting the necessary investment economies.

A. C. MONTEITH
Manager, Industry Engineering, Westinghouse Electric & Mfg. Co.

THE wartime performance of the electric industry has confounded its worst critics and surprised its staunchest supporters. But the industry must not rest long on these laurels. The hazards of complacency are well known. The mark of a healthy industry is its progressive growth. Precedents and customs that have reached the limits of their possibilities must be pruned out so that new growth can be stimulated by new and changing conditions.

The steady decrease in price of electrical energy, shown in Fig. 1, is a delight to us all. It has stimulated much development in all industries. Things impossible 20 years ago are being done electrically today to make our way of life better.

That costs of producing electric power have not declined as rapidly as the power prices is somewhat distressing. There is trouble ahead—serious trouble—if the trends continue as indicated. A reasonable margin between cost and price of energy must exist if the industry is to remain virile. To increase prices would be difficult, if not impossible. Even if it could be accomplished its desirability is questionable. The conclusion is obvious. Find methods of reducing costs. This is not easy, because reductions in cost must not be made at the expense of service reliability or by cashing some of the system reserves. A reasonable reserve capacity should be maintained for several reasons, the best of which is to withstand the impact of war and other emergencies, of which we have just had such a vivid example.

Methods of Reducing Capital Costs

Any reduction in capital investment also affects maintenance, taxes, and other costs that determine the overall cost of production. Capital costs only are considered here. Methods of reducing capital costs of central-station power systems could be the subject of a large book. A few of the chapter subjects for such a book might be the following:

1—Use equipment up to its economic limit of loading, especially for short-time overloads occurring infrequently in emergencies.

2—Provide wattless capacity at the loads to derive the greatest kilowatt system capacity per dollar of investment.

3—Encourage high load-factor loads, which result in the delivery of a maximum number of kilowatthours for a given system investment.

4—Eliminate spare equipment where justified by the superior reliability of modern equipment with short-time overload capacity or where portable equipment can be used.

5—Encourage standardization of methods and equipment to minimize designs, drawings, tools, jigs and fixtures for heavy apparatus and in addition, allow volume production when manufacturing the smaller apparatus.

6—Simplify system layout and reduce component parts of the system to a minimum. This is the subject for consideration here.

System layout should be reviewed now to take into account the accumulated improvements in apparatus and system designs. This is important because only up to a certain point do increased costs result in improved service. Then the point of diminishing returns is reached, and costs become excessive for a small improvement.

Consider the example of Fig. 2, drawn to illustrate this point, which does not necessarily represent any particular system. Assume that for the equipment available in the period between 1920 and 1930 it was necessary to put sufficient apparatus, lines, etc., into the system to provide the quality of

This article is based on a talk by Mr. Monteith given before the Edison Electric Institute, New York, June, 1944.

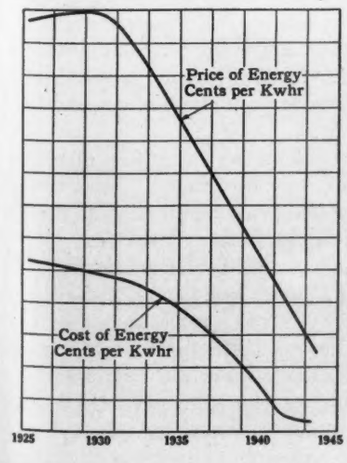


Fig. 1—*The cost of electric energy and its selling price are both declining, but, unfortunately, not at the same rate.*

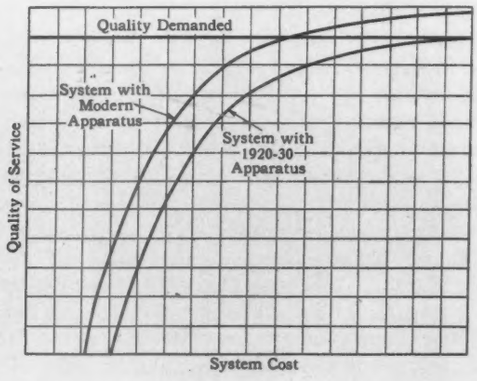
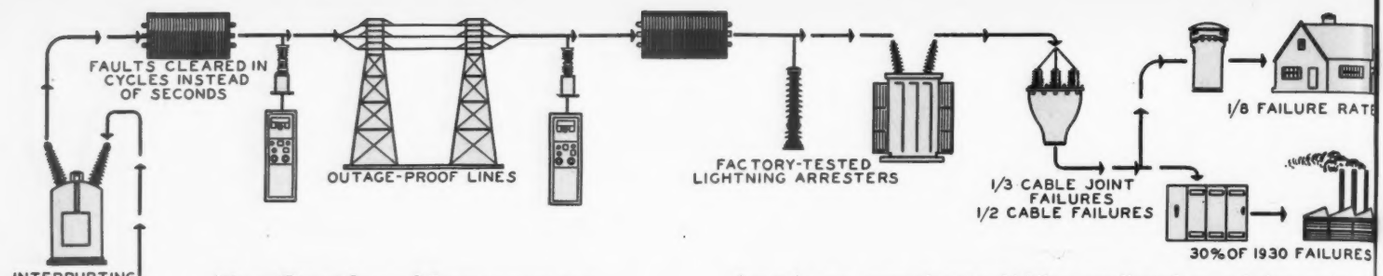
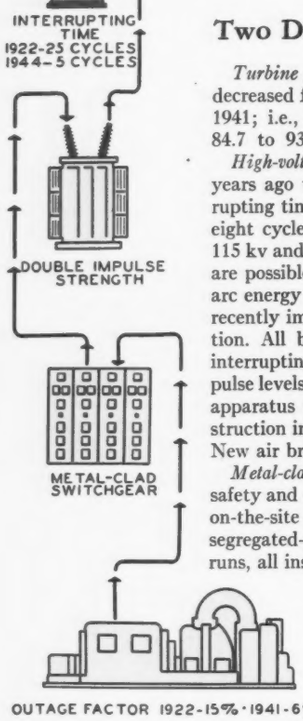


Fig. 2—*A given order of service can be provided at lower investment in equipment than was possible two decades ago.*





Two Decades of Improvement

Turbine generators—Total outage factor has steadily decreased from 15.3 percent in 1922 to 6.11 percent in 1941; i.e., the availability factor has increased from 84.7 to 93.89 percent.

High-voltage circuit breakers—Interrupting time 20 years ago was about 25 cycles. First published interrupting time in 1929, 12 cycles, was in 1930 reduced to eight cycles. Now the published time for breakers of 115 kv and more is five cycles, and three-cycle breakers are possible. Reduction is effected by greatly lessened arc energy and gas formation. Twenty-cycle reclosing, recently impossible, effects economies in line construction. All breakers are now factory tested to stated interrupting capacity. Modern breakers meet basic impulse levels. Insulation can be coordinated with related apparatus to provide uniform surge protection. Construction improvements lengthen maintenance periods. New air breakers minimize fire and explosion hazards.

Metal-clad switchgear with modern breakers provides safety and outage-reducing features unobtainable with on-the-site assemblies, and provides the equivalent of segregated-phase operation with much less space. Bus runs, all insulated for full voltage, have an almost perfect safety record.

System relaying with modern relays and high-speed breaker faults are commonly cleared in six to nine cycles, with four possible, in contrast to a few seconds two decades ago.

Transmission lines—Lower tower-footing resistance, more adequate shielding, coordinated tower designs make high-voltage lines almost outage proof. High-speed fault clearing reduces arc damage, permitting immediate reclosure. Some lines have had a perfect ten-year record. Faults on one 66-kv line were reduced from 45 outages per 100 miles per year to three by reducing footing resistance. Further reduction to one possible by adequate shielding. Use of protector tubes makes low-voltage lines virtually outage proof. Tubes added to every second pole of a 13.8-kv line reduced outages from 42 to 2.

Cables—Faults in joints have been reduced by two thirds since 1923. Faults in cables themselves have been reduced by one half.

Network transformers—Failures have dropped to one third since 1930.

Lightning-protection devices are now factory tested to insure uniformity. They can discharge most direct strokes, yet give protection.

Power transformers—Improvements leading to greater reliability since 1922 include tap changing under load, better oil, sliverless copper, paper-insulated conductors, brazed oil connections, better gums and varnishes, inert gas over the oil, surge-proof features, better tank seals, stronger mechanical parts, better conductor bracing, vacuum filling, steep-wave-front testing, and loading by copper temperature. Impulse strength, now factory measured, has doubled; protection rate of arresters has been halved. Surge voltages are now held by protective devices to about one half of surge strength of the transformer winding. Auxiliary cooling equipment provides extra reserve transformer capacity.

Distribution transformers—Impulse strength has been greatly improved, permitting use of protective devices that can discharge almost direct stroke. The failure record for modern protective devices in 1 900 000 transformer years of service is 0.006 percent per year. In past decade, failures from all causes on one representative group of transformers dropped from 0.8 to 0.1 percent per year. Outage expectance on transformers with protective systems of ten years ago was up to 20 percent per year; now it is less than one percent. Much higher loading is now possible with safety, which reduces system costs.

service indicated. However, apparatus, line designs, and methods of operation have been improved, so that for systems with modern apparatus, the same quality of service can be obtained with less investment. This example may be exaggerated for some systems, but it illustrates the point that full advantage of improvements in equipment should be taken when plans for changes or extensions are made.

The examples given of improvement of two decades in the components of electrical systems, shown above, while incomplete, suffice to show that in the last 20 years the reliability of equipment has materially improved. This should be taken into account. Also, pyramiding of probabilities should be eliminated where possible to minimize the amount of equipment necessary to secure a given reliability of operation. If too much equipment is installed in an attempt to secure an extremely high degree of reliability, it is quite possible, actually, to increase instead of decrease the probability of outage.

In capitalizing on the accumulated improvement in equipment to reduce system investment, where is the greatest return possible for a given effort? The three main components of a power system are generation, transmission, and distribution. Of the total power-system investment, 28 percent is in generation, only 14 percent in transmission, but in distribution lies 58 percent. This is significant and indicates possibly where the most profitable efforts may be directed.

In general, a thorough, well-integrated job has been done in the generating component of power systems. Attention has been focused on the engineering and building of power stations because they represent large investments infrequently made. In 20 years, the cost of large generating stations has decreased steadily and very materially, even in the face of providing more elaborate means of retrieving Btu's with superheaters, economizers, etc. Meanwhile, the amount of coal burned to produce a kilowatthour has been pushed down from three pounds in 1920 to a low of 1.31 pounds in 1942. Some further decrease in fuel cost can be expected, but it will be slight considering the overall cost of a delivered kilowatthour. Possible further decreases in station cost are also small.

Transmission systems also have been built up of relatively large incremental investments so that considerable effort has been concentrated on the engineering and building of these lines. The capacity of a few systems can be increased by adding high-speed relaying and by revamping breakers for faster operation. Series capacitors can be used to neutralize the reactance of the system where the existing conductors are large enough to carry the increased load. The total possibilities for savings in transmission, however, are minor in comparison to what has already been done.

In general, distribution systems have been built up of small increments, sometimes purchased by different branches of the utility organization and put together and operated. The tendency has been to emphasize perfection of service.

Some of today's standards of distribution are predicated on apparatus as it performed 20 years ago. Consideration should be given to a review of the system as a whole and particularly the distribution system, taking these factors into account. When making changes or extensions in the distribution system, I believe the amount of equipment can be reduced, thereby lowering costs without impairing service.

Several schemes for the reduction of distribution costs are

worthy of consideration. The central-distribution substation can be used or small one- or two-circuit distribution substations can be located at many points on the system. In feeding industrial loads, loop feeders with elaborate tap-point equipment can be used, or multiple radial feeders, or a number of combinations with their varying degree of cost can be used. The selection will depend on the importance of the customer process and the size of load. Again, in the residential and commercial areas, consideration can be given to radial systems, low-voltage-network systems, or primary-network systems, depending on the load density and the type of service required. In other words, there is a large variety of schemes for furnishing service to industrial customers, no one of which provides a universal answer.

Economies with Indoor Substations

A typical distribution substation, *A*, Fig. 5, is provided with multiple high-tension buses, and with main and auxiliary breakers on the secondary bus and a transfer bus for cutting regulators in and out of service. Also, single-pole breakers have frequently been used so that one line is opened on a single-phase fault. In other words, with a 2000-kva feeder, only 666 kva would be lost for a single-phase fault. The equipment cost of this station is assumed as 100 percent or $22 per kva of firm demand at the substation (which will be the basis of comparison of all kva costs).

Station *A* does all that a distribution substation should do, but its cost is high. Some of the features that lead to its high cost are: the use of single-pole switching on the 4-kv primary feeders and the individual voltage regulation on any phase. Most companies have found these refinements unnecessary. The use of 4-kv auxiliary and transfer buses and the many disconnecting switches to minimize the time of a service outage should a failure occur in a substation, and to facilitate maintenance of equipment, is expensive. In the light of equipment available in the 20's this might have been justified, but with modern equipment this station is unnecessarily elaborate.

The introduction of standard metal-clad switchgear with removable multiple-operated, three-pole breakers and the use of triplex regulators result in considerable saving. Substation *A* has been modified to permit the use of this modern equipment which becomes substation *B*. Substations *A* and *B* are identical in performance except *B* is arranged for three-phase feeder operation instead of single-phase operation. This results in a substation-equipment cost of 63 percent or $14 per kva. Installation cost, although lower than that for the first substation, will be relatively high when building and wiring costs are included.

In addition to the use of modern standardized equipment, further cost reductions can be made by changing the fundamental substation diagram. Substation *C* illustrates this point and can be used in building new substations or rebuilding old ones. Except that no 15-kv substation transformer breakers are used, the 15-kv switchgear layout is basically the same as that of substation *A*. It has been modified only in detail to utilize standard metal-clad switchgear. Beyond this point, however, this substation is unlike substation *A*. It is designed on a 4-kv unit-feeder basis. There is no 4-kv bus in this substation. With this type of distribution, employing relatively large circuits, facilities must be provided outside the substation on the 4-kv feeders for switching the load of any feeder to two or more adjacent feeders so as to restore service quickly following a feeder failure. Because these facilities must be available elsewhere in the system, even a 4-kv transfer bus has been omitted from substation *C*. External switches are utilized when it is necessary to take a substation transformer out of service. Any circuit breaker can be withdrawn from its compartment and a spare breaker inserted.

The outstanding advantages of substation *C* are simplicity, unit design with accompanying flexibility for load change, decrease in possible 4-kv short-circuit current and the accompanying system voltage disturbance, lower losses, and its lower cost. The equipment for this substation will cost approximately 54 percent of that of substation *A* or $12 per kva.

The appearance of this equipment when installed in a substation building is shown in Fig. 4. The high-voltage, metal-clad switchgear with air circuit breakers extends across the front of the building. To it are bolted the feeder units, each consisting of an air-cooled transformer with automatic tap changing under load and a 4-kv air circuit breaker. The transformers are air cooled, hence all equipment can be located indoors. This makes possible the unit type of construction where all connections between the different pieces of equipment are made with short sections of metal-enclosed bus. This type of equipment eliminates many potheads, cables, and conduits required when oil-cooled transformers are used outside the substation building. It allows complete flexibility in adding equipment or in removing in step with load changes.

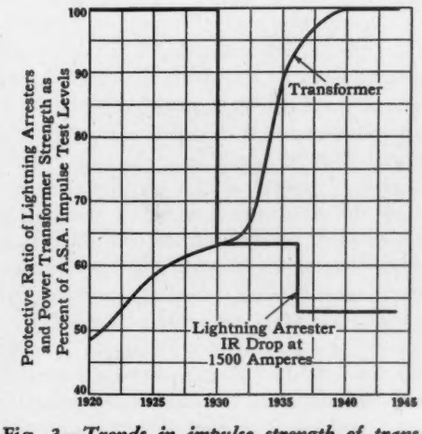


Fig. 3—*Trends in impulse strength of transformers and lightning-arrester protection ratio.*

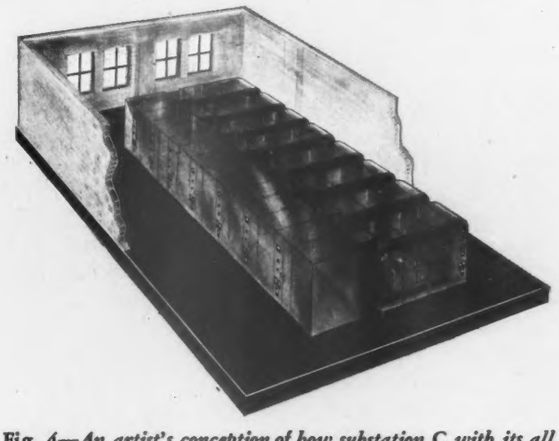
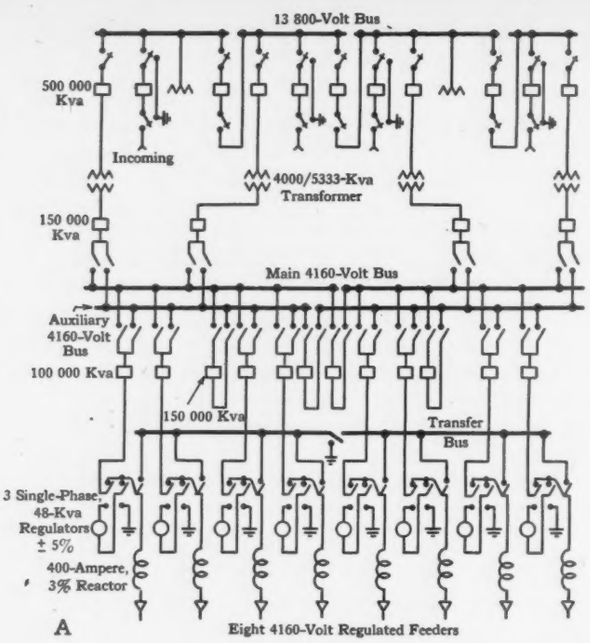
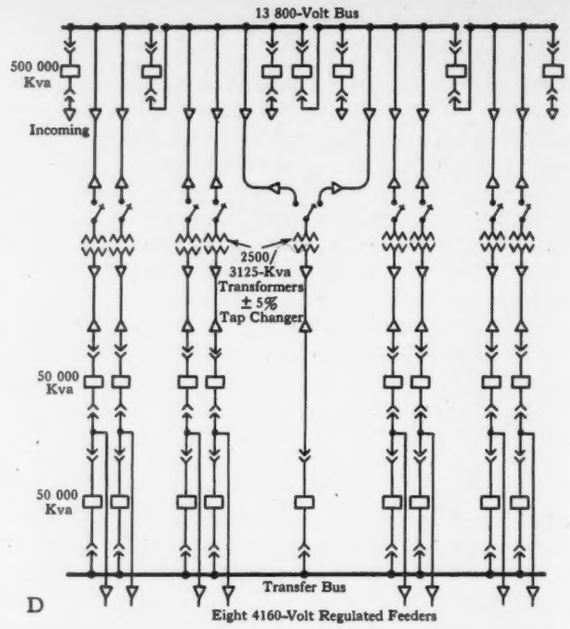
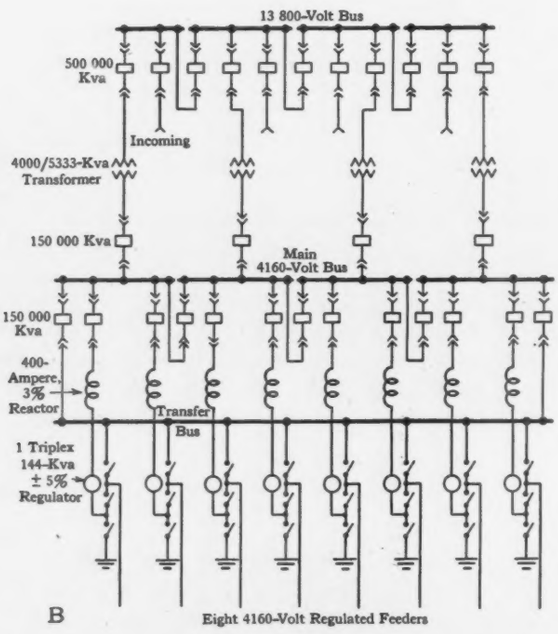


Fig. 4—*An artist's conception of how substation* C *with its all air-cooled circuit breakers and transformers might appear.*







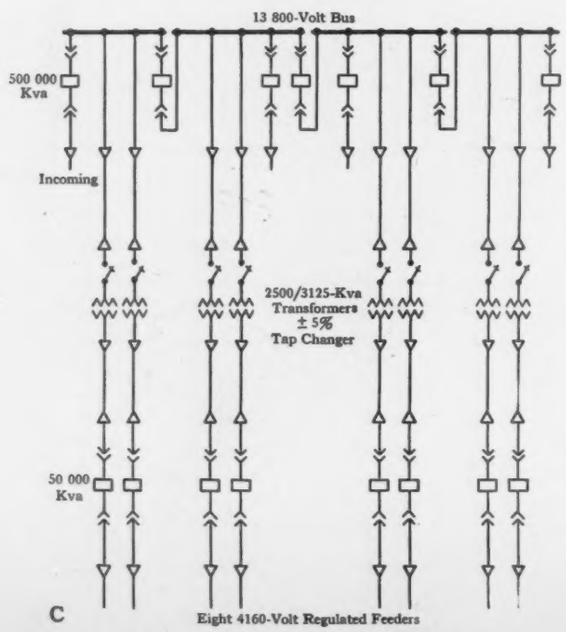


Fig. 5—*Various arrangements of substations showing different degrees of simplification.* **A** *is the more elaborate type of station often used heretofore.* **B** *is similar to* **A** *except arranged for three-phase operation.* **C** *achieves considerable simplification through a major station redesign.* **D** *is a modification of* **C**, *made necessary in the absence of external switching.*

The location of all the substation equipment indoors naturally raises the question as to the size of the building required to house it. From Fig. 6, showing the floor plan of a building to house substation *A* and substation *C*, the considerable difference in apparatus expense and cost of installation is apparent.

Transformers and voltage-regulating equipment of substation *C* cannot be as conveniently de-energized for maintenance as in the case of substation *A* without dropping load. This is because load must be switched outside of the substation from one feeder to others. Where external feeder-switching equipment is not available, this substation can be modified to substation *D*, as shown in Fig. 5, to include a transfer bus, thereby permitting all switching for maintenance of station equipment to be done in the station. To obtain this greater convenience for maintenance, the equipment cost for *D* is $2 per kva more than for *C*, with a slight increase in building and installation costs.

The substations discussed can be constructed with outdoor equipment. For substations *C* and *D*, the equipment arrangement and cost are approximately the same whether installed indoors or outdoors. Outdoor oil-insulated transformers are substituted for the indoor air-cooled transformers. The substation space will be increased about 25 percent because of the increased size of the outdoor transformers.

Where new designs are made and the greater reliability of equipment and lines is taken into account, the total installation and equipment costs of a substation can be less than half those of the more elaborate substations designed and built on the basis of former service records and experience with the older types of equipment. Why then can substations *C* or *D* be considered when substation *A* was once deemed necessary? The answer lies in the greater reliability of apparatus and lines. The 4-kv cables, for example, have only about one third the probability of failure now that prevailed in the 20's and transformers have been improved even more. This alone justifies a change from single- to three-phase operation as the outages per customer caused by cables and transformers should be about the same or even less. The complicated bus

arrangement was provided so that feeders could be switched in case of failure of equipment in the substation itself. The likelihood of failure of equipment in the substation has been minimized because of the complete factory testing. Metal-clad switchgear with complete enclosure of all live parts, air-insulated transformers with tap changing under load, and air circuit breakers throughout allow placing all the equipment together in one building. The necessity of single-phase regulation in all cases is questionable.

These same arguments hold for open lines as for cables. Overhead lines are now being built with self-clearing characteristics. However, the majority of persistent faults are cleared by de-energizing the feeder. Service is then automatically restored in a few seconds.

Industrial Power Supply

Another opportunity for economy is in the equipment for distribution systems serving small and medium-size industrial customers. Many of these are supplied from high-voltage loops as shown in Fig. 7. One practice is to supply each of a number of industrial substations with equipment as shown in substation *J*, which will be the basis of comparison for all schemes. This and all other substations in Fig. 7 are designed to serve an industrial customer having a load demand of 1000 kva. Substation *J*, costing $22 per kva, provides excellent service to the customer. A loop fault on either side of the substation does not interrupt service. A failure of the transformer, of course, interrupts the power supply until a good transformer is connected in its place. Transformers are so reliable, however, that additional expense cannot normally be justified to prevent a service interruption that probably will not occur once during the life of the substation. Substation *J* probably gives better service continuity than can be justified for many industrial customers.

The probabilities are that a fault will occur about once every five years on one of these industrial loops. If so, substation *K*, costing about $15 per kva or 69 percent of substation *J*, can be used to provide adequate service to the great majority of industrial customers. If a fault occurs on the 13.8-kv loop to the right of substation *K*, the customer's power supply is interrupted but his service can be quickly restored by opening the circuit breaker in the secondary leads of the transformer, closing the transformer primary switch to the left to connect the transformer to the good section of the 13.8-kv loop, and reclosing the air circuit breaker. Except in this one case of trouble, which probably will cause interruption only once in 15 to 20 years, substation *K* provides substantially the same quality of service as does substation *J* and has an overall saving of about 30 percent.

The few customers requiring best possible service continuity can be supplied most economically through substation *L*. This substation gives somewhat better service than substation *J* at an equipment cost of approximately 92.5 percent or about $20 per kva. By using substation *K* for 90 percent of the industrial customers and substation *L* for 10 percent of them, instead of using substation *J* throughout, an aggregate cost saving in industrial substation equipment of 29 percent is obtainable.

A further saving in investment can be made by using two radial feeders to supply a group of industrial customers, as shown on the right of Fig. 7. Using this radial supply scheme, the length of cable required will range from equal to about 50 percent more than that required when using the loop supply, depending upon the geographical location of the customer served. The possible reduction in size of cable and the fact that both radial feeders can be carried in one duct bank, however, makes the cable-supply costs for either loop or radial feeder about equal. Therefore, the savings in substation costs when using the radial supply represents a net saving. Substations *M*, *N* and *O* are comparative to those discussed for the loop feeders. When using radial feeders and substation *N* for 90 percent of the customers and substation *O* for 10 percent of the customers, a saving of 62 percent in substation equipment cost is made when compared with using

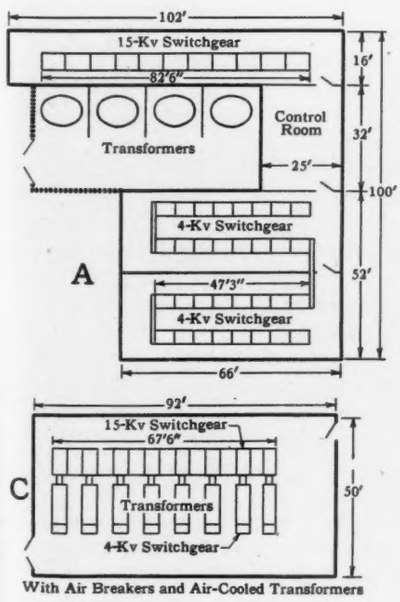


Fig. 6—*Comparative spaces occupied by the substations* A *and* C.

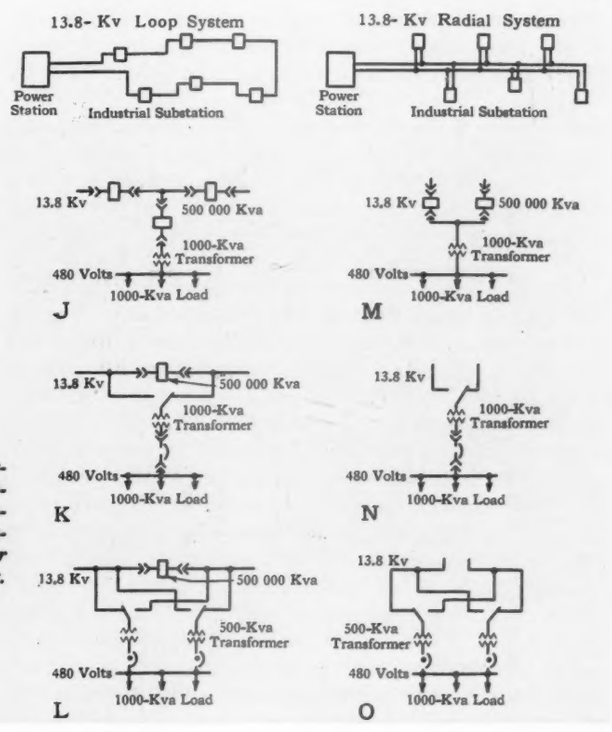


Fig. 7—*Possible arrangements of a 1000-kva industrial substation supplied from loop- and radial-feeder distribution systems.*

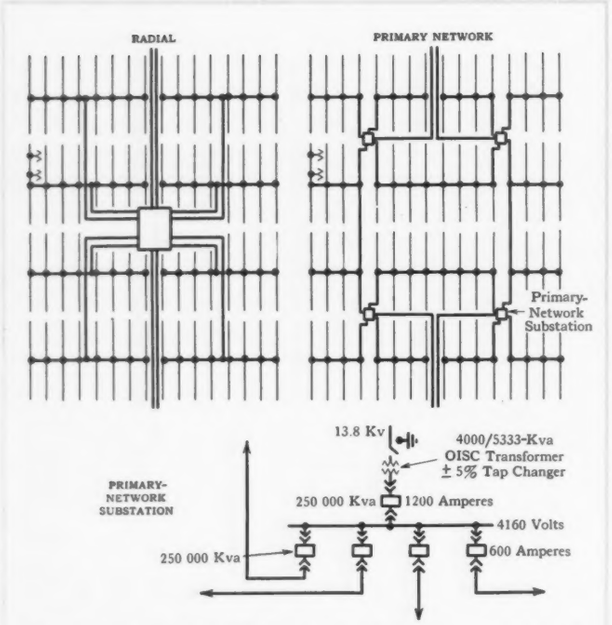


Fig. 8—*The supply of domestic and light commercial loads.*

the 13.8-kv loop feeder and substation *J*. Even if substations *K* and *L* are used, as recommended with the loop feeder, the saving in substation equipment cost is 47 percent over the radial feeder and substations *N* and *O*.

The radial feeder and substation *N* make it economical to supply in this manner many small industrials now supplied through the large distribution substations along with the residential and small commercial customers. This releases distribution-substation capacity for residential load growth.

Primary-Network Distribution

The predominant method of supplying power to residential and small commercial customers is over radial circuits from relatively large distribution substations, as shown in Fig. 8.

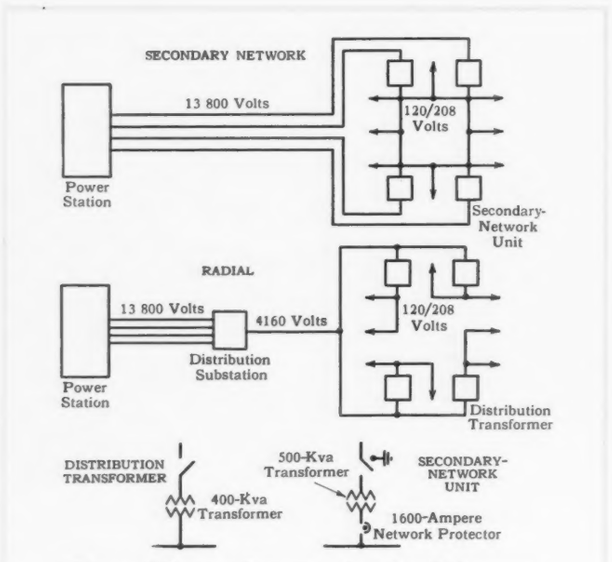


Fig. 9—*The secondary-network and radial systems.*

To secure the best economy with such a distribution system the substation should be located near the load center of the area it serves. If this is not done, the lengths of the main 4-kv feeders become excessive, with consequent high investment and losses. The substation must be located and built before the area it is to serve is well developed. Because distribution-system loads are continually growing and shifting unpredictably, a substation can seldom be located where it should be, to serve its load five or ten years after it is built.

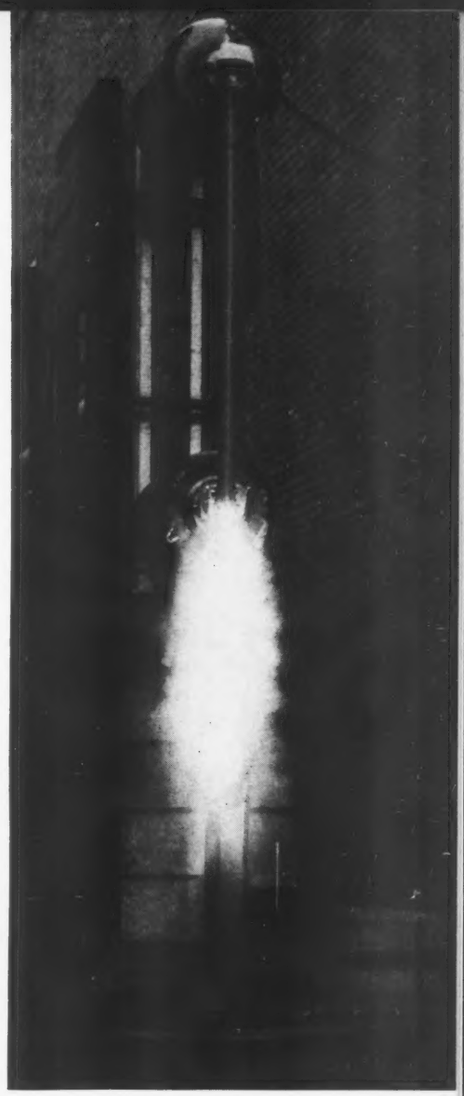
The primary-network system is more flexible. In it a much larger number of relatively small substations are located at or near what would be the load centers of the 4-kv feeders in a system using large substations. These substations are tied together on their 4-kv sides, as shown in Fig. 8, to provide service at least comparable to that rendered by the radial system. The equipment cost of one of these substations using outdoor equipment is about $11 per kva compared with $12 for large substation *C*. The fact that these small substations can usually be located outdoors with only a fence or a wall around them makes their cost advantage even greater, because the large substation building cost must be added to that of its equipment. When using a primary-network system the cost of the 13.8-kv circuits is usually greater than when using a radial system as discussed. In most cases, this will be offset by the saving in the 4-kv circuit cost.

Secondary-Network Distribution

Secondary-network systems in areas of high load density are now accepted. Greater use of this type of system could be made to lower distribution costs. Small commercial loads with relatively high load density exist in many spots throughout city areas. These areas, now being fed through distribution substations as shown in Fig. 9 can be given better service in many cases at less cost from small secondary networks supplied directly over 13.8-kv circuits, of the type shown in the figure. The secondary network eliminates one voltage transformation and thus frees distribution substation capacity for residential and small commercial loads. A network protector on each transformer bank results in higher cost than a transformer in the straight radial system as illustrated in Fig. 9. The total equipment cost in the network system is less than in the radial system, however, because there is no distribution substation cost to be included for this scheme. For example, based on the cost of equipment shown in this figure and the costs for substation *C*, the equipment cost per kva of demand at a customer service is about $8 for the network system and about $11 for the radial system. Thus, the secondary network shows a saving in equipment cost of about 20 percent.

If as careful engineering is done in connection with distribution as has been done with generation and transmission schemes, the system arrangement can be simplified and still render the service demanded by the customers. Equipment and lines have increased in reliability over the last 20 years to the point where simplified substations and systems can be considered that would have been entirely impractical from a service point of view two decades ago. This will mean less equipment plus a decrease in maintenance and other costs.

This is just one chapter of the book on power-system economies that the industry will have to write for itself if it hopes to maintain its illustrious record of high-quality service and low prices for its goods. These ideas are presented in the hope that they will promote increased study not only in the distribution component—where the most promising money-saving prospects lie—but also in other parts of the power system as well.



Modern High-Voltage Fuses

An electrical fuse is—or was in the early days—a simple thing. But now we have, in the high-voltage field alone, cutouts, expulsion fuses, repeater fuses, liquid fuses, boric-acid fuses, fuses that open quickly and others that open quite slowly. Each type has its own ratings for voltage, load current, and interrupting current. The difference in function between breakers and fuses, while real, becomes less obvious. A review of underlying fuse principles will help reclarify this matter.

H. L. RAWLINS, *Manager*
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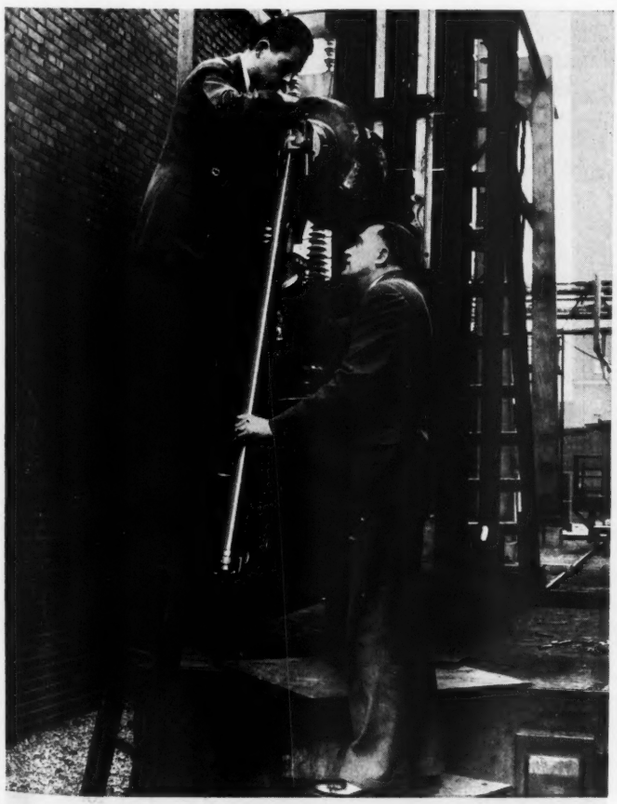
Protective Devices Engineering
Westinghouse Electric & Mfg. Co.

A FUSE, according to AIEE definition, is "an overcurrent protective device with a circuit-opening fusible member directly heated and destroyed by the current passing through it." The prime function, therefore, of a fuse is to protect the power source or the connected apparatus by interrupting the circuit under fault conditions. This could be done by other types of circuit-interrupting devices, but a fuse is used primarily because of its small size and low cost. Fuses are ordinarily applied as short-circuit protection for power transformers and most transformers on distribution systems, as distribution-line sectionalizing devices, as short-circuit protectors for motor starters, for the protection of high-voltage capacitors, on high-voltage d-c railway circuits, and on street-lighting transformers.



Mr. Wallace, left, and Mr. Rawlins check a high-voltage fuse before test in an outdoor section of the high-power laboratory.

A fuse is identified by its load current, voltage, and interrupting ratings. The maximum load current of a fuse is determined by its temperature rise, which should not exceed 30 degrees at the fuse clips. For renewable fuses, it is necessary to state both the maximum current rating for the fuse holder, which is the part used again after the fuse has operated, and for the fusible or renewable element. The time-current characteristic curve of the fusible element must be considered when attempting the coordination of fuses with other devices.

There are two approved standards for rating fuses. These ratings, N and E, have been established by EEI and NEMA. The N standard has been in force for many years and is applicable to the universal cable-type fuse links used in distribution-type cutouts. Such a link will carry 100 percent of its rated current continuously but will blow at less than 220 percent of its rated current in 300 seconds.

The recently adopted E standards, which apply to modern fuses, require the fuse to melt at a current of 200 to 240 percent of rating in exactly 300 seconds for fuses up to and including 100 amperes, and currents of 220 to 264 percent of rating in exactly 600 seconds for fuses above 100 amperes. The fuse must carry 100 percent of the rated current continuously without exceeding a rise of 30 degrees C at the fuse clips.

The rated voltage of a fuse is the highest rms voltage at which it is designed to operate. It is expected to interrupt any current within its rating at this voltage and to maintain the circuit open with rated voltage across it after it has blown.

The interrupting rating of a high-voltage fuse is usually given as the maximum asymmetrical rms amperes that can be interrupted at the specified voltage and duty cycle. To provide a basis of rating comparable to circuit breakers and to eliminate confusion, manufacturers are beginning to list along with the interrupting rating of power fuses, the three-phase kva rating of an equivalent circuit breaker. This rating corresponds to the symmetrical maximum fault kva for a circuit that could produce an asymmetrical current equal to

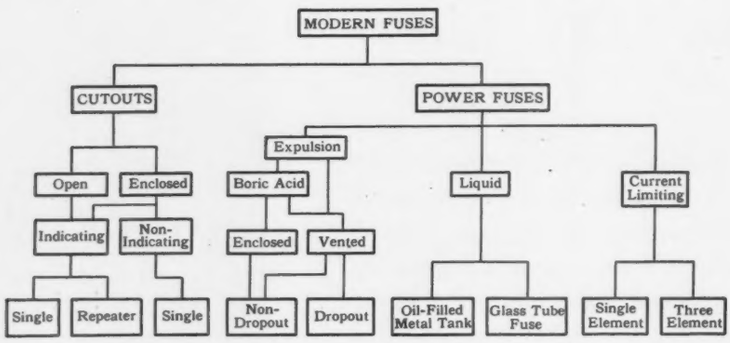


Fig. 1—***This chart shows the relationship between the classes of modern fuses.***

the current-interrupting rating of the fuse. The kva rating is the asymmetrical rms current-interrupting rating of the fuse divided by 1.6, the asymmetry factor. The new current value is then multiplied by the circuit voltage and the three-phase factor (1.73). The asymmetry factor has been determined as representing the increase in the interrupting duty required of a power fuse when interrupting an asymmetrical instead of a symmetrical current.

In the application of distribution cutouts, the asymmetry factor is 1.2. The use of a 1.6 factor for power fuses and a 1.2 factor for distribution cutouts results from the difference in characteristics of the circuits in which they are usually applied. A power fuse is usually close to the source of power where there is little damping effect in the line, whereas a distribution cutout is usually in an extended distribution system having a resistance component high enough to provide substantial damping.

The inherently fast operating characteristics of fuses require consideration of an asymmetry factor when making a fuse selection. With power circuit breakers, the time for operation is usually slow enough to allow the d-c component of the circuit to decay so that the breaker interrupts only the symmetrical short-circuit current of the system. The fuse, on heavy faults, usually interrupts by the end of the first half cycle of current.

Installed in an outdoor switchhouse, this boric-acid, current-limiting fuse will interrupt a 60 000-ampere circuit at 2.5 kv.

Equipment Available

Cutouts—Fig. 1 indicates how modern equipment divides readily into two classifications, the first being distribution cutouts and the second, power fuses. The cutout, a low-capacity fuse intended for use in a distribution system, is an assembly of a fuse support and fuse holder of relatively low interrupting rating which is designed to receive a universal type of cable link. Cutouts fall into two major classifications, the open and the enclosed types. The open cutout is used most commonly on distribution circuits above 7500 volts. The enclosed cutout is generally applied to circuits of 7500 volts or less.

A variation of the indicating cutout is found in the repeater type where two or more fuse tubes are mounted so that the operation of the first connects the second tube into the circuit. This allows clearance of temporary faults and prompt restoration of service by the circuit-reclosing action of the second fuse tube. Cutouts are applied almost exclusively on distribution circuits for outdoor use.

For some indoor locations, the cutout has sufficient interrupting ability. The ratings of enclosed-type cutouts are 5 and 7.5 kv at 50, 100, and 200 amperes, with corresponding interrupting ratings of 1000, 3000, and 5000 amperes. The ratings of open-type cutouts are 5, 7.5, and 15 kv at 50, 100, and 200 amperes, with respective interrupting abilities of 1200, 2000, and 4000 amperes. These ratings conform to NEMA standards established for these classes of fuses.

Power Fuses—The main divisions of power fuses are expulsion fuses, boric-acid fuses, liquid fuses, and current-limiting fuses. While the boric-acid fuse can be classed as an expulsion fuse, common usage has restricted the term "expulsion fuse" to fiber-tube fuses using flexible conducting elements within the tube. Therefore, the boric-acid fuses and the expulsion fuses are classified separately.

Expulsion Fuses—In the expulsion fuse, a tube of solid gas-generating material is mounted between the circuit terminals so that a flexible shunt can be connected through the tube with a fusible element usually at one end. Interruption is caused in this type of fuse by a blast of gas originating in the decomposition of the solid tube by the heat of the arc. This blast of gas blows the ionized arc products out of the tube, and continues to do so through current zero, thus causing deionization of the arc space. Obviously, some noise and demonstration attend the interruption of high currents. This factor should be considered when applying this type of fuse. Expulsion fuses are either fixed or dropout, the trend being toward the dropout fuse for the higher voltages.

Boric-Acid Fuses—In the boric-acid fuse, the tube is filled by a series of blocks formed from powdered boric acid under high pressure. A hole through the center of each block forms the bore. When an arc is drawn in the boric-acid tube, the generated gas consists principally of steam, formed from the water of crystallization of the boric acid. The steam is incom-

bustible and thus helps to maintain high dielectric strength around the fuse under operating conditions. A further advantage results from the fact that the steam can be condensed to water vapor in an ordinary surface type of condenser, consisting of spaced copper plates arranged in a container fastened to the vented end of the fuse holder. Condensing the steam eliminates the gas blast. Because of this, the fuse can be made with smaller clearances and will have no demonstration in operation. This permits a totally enclosed fuse with high interrupting ability—one suitable for indoor application.

A new principle was applied in some boric-acid fuses to decrease the length of the interrupting element. An additional small bore is provided in the boric acid and, by means of suitable shunts, the fault current is switched into the small bore where it is interrupted if the current is small. This permits the larger bore to interrupt only the large currents which are shunted back from the small bore. Thus, the bore diameter is correlated with the magnitude of the short-circuit current, permitting efficient use of the boric acid to obtain high voltage gradient.

The boric-acid fuse is made in both fixed and dropout forms. The dropout is available for load currents up to 200 amperes with an interrupting ability of 5000 amperes at 138 kv. The fixed type has an interrupting ability of 40 000 amperes at 2400 volts, and of 20 000 amperes at 33 000 volts with a maximum load current of 400 amperes. For most indoor applications, the condenser-type boric-acid fuse is used to provide noiseless operation.

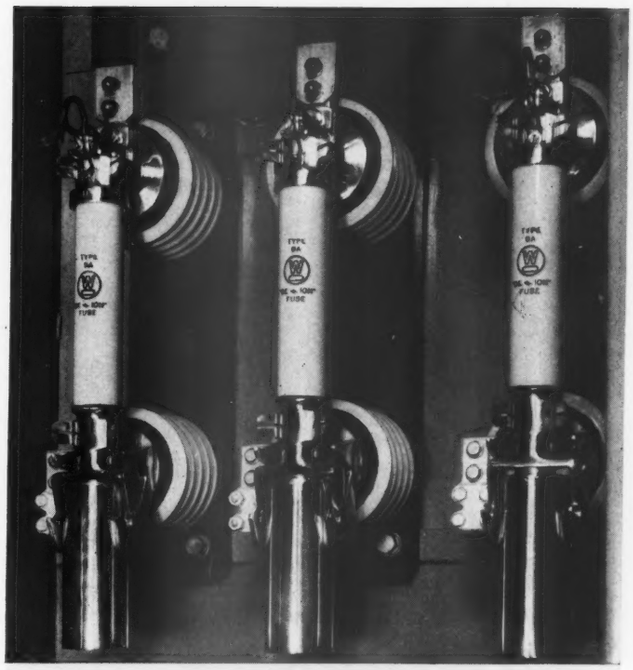
Liquid Fuses—The liquid fuse still enjoys popularity where applicable, but its use recently has been curtailed in favor of dry-type fuses. One common form of liquid fuse consists of a glass tube with suitable end caps between which are connected the fuse element and a flexible spring-retracted shunt. On overload, the fuse link melts and the arc is drawn into the liquid by collapse of spring and shunt. These units are made in several current sizes up to 400 amperes and in voltage sizes up to 138 kv.

Another common form of liquid fuse is the oil-filled cutout in which the fusible element is under oil and is commonly mounted on a rotating frame so that the circuit can be interrupted by moving an external handle. Thus, the oil cutout acts as a load interrupter as well as a short-circuit interrupter. This type of cutout is usually applied in subways because it is available in the submersible type.

Current-Limiting Fuses are divided into two types, the single-element and the three-element fuses. These are dry-type fuses that operate on the principle of interrupting currents of large magnitude by requiring the fuse element to melt far in advance of the possible peak current of the first half cycle. The fuse is so designed that the melting of the element introduces a high arc resistance, which, in turn, holds the circuit current to that within the abilities of the fuse.

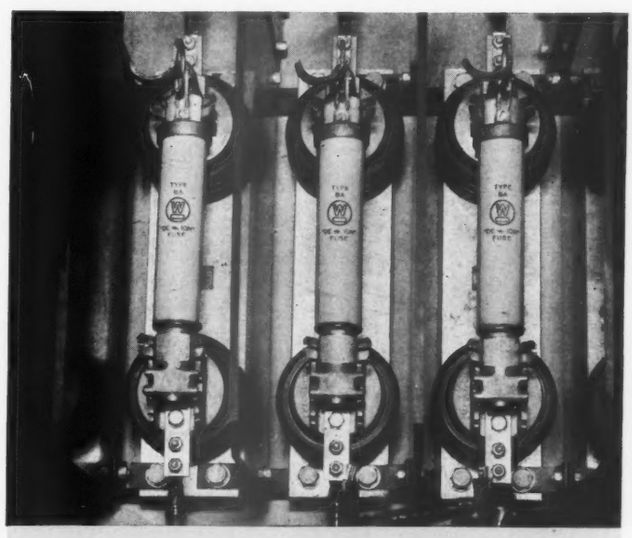
The single-element current-limiting fuse consists of a small silver wire suspended in a body of fine sand and relies for its interrupting ability upon the rapid de-ionizing of the arc space by the condensation of the arc products on the sand.

The three-element current-limiting fuse consists of a circuit-clearing or clean-up fuse and a current-limiting device in series. The clean-up fuse is a boric-acid fuse supplied with a condenser so that it can be totally enclosed. The current-limiting element consists of silver wires mounted in longitudinal grooves in a round fiber rod such that the width of the groove is about equal to the diameter of the silver wire. When the silver melts, a high arc voltage results to cause the current to transfer to a metallic resistor in parallel with the current-limiting element. The resistor definitely controls the surge voltage following circuit interruption.



The condensers, shown as cylinders at the bottom of these boric-acid fuses, eliminate all noise and demonstration of operation.

Current-limiting fuses are ideal for the protection of potential and small operating transformers and are made for this service for voltages up to and including 23 kv. These are also made in current ratings up to 200 amperes at 5 kv and 100 amperes up to 23 kv. The interrupting rating is higher than for any other fuse and is 60 000 amperes at 2.5 and 5 kv, 80 000 amperes at 7500 volts and 50 000 amperes at 15 kv. They are totally enclosed, eliminating all external disturbance and their current-limiting action reduces magnetic stresses. They can be coordinated with motor starters to produce a



These vented-type boric-acid De-ion fuses have no condensers and are used where noise and demonstration are of no import.

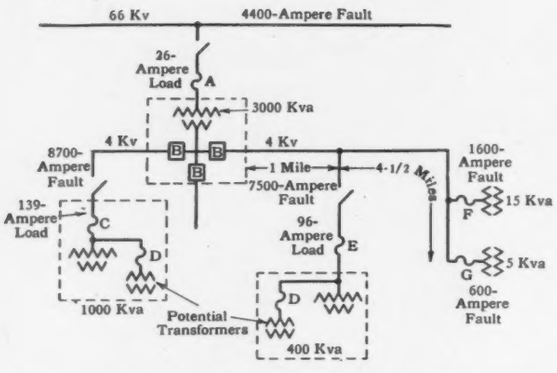


Fig. 2—*Wiring diagram of typical high-power fuse applications.*

combination that can be connected to a high-capacity bus. Such coordination requires extensive study of all the characteristics of both the starter and fuse. The fuse must coordinate with the thermal element of the starter, its interrupting ability, and short-time rating, as well as coordinate with the electrical characteristics of the motor itself.

Factors Affecting Fuse Selection

Interrupting Requirements—The interrupting requirement may be low if the fuse is located some distance from the substation on a rural distribution line, or it may be extremely high when the fuse is connected to the generating-station bus. In applying a distribution cutout, the symmetrical fault current of the system at the location under consideration is determined and a cutout chosen with a current-interrupting rating at least equal to 1.2 times the symmetrical fault current.

The power fuse is chosen so that its kva rating equals or exceeds the calculated symmetrical fault kva possible at that point. This is consistent with the practice followed in applying circuit breakers. If the symmetrical fault current of the circuit is known, a fuse should be selected with a current-interrupting ability equal to at least 1.6 times the system symmetrical fault current.

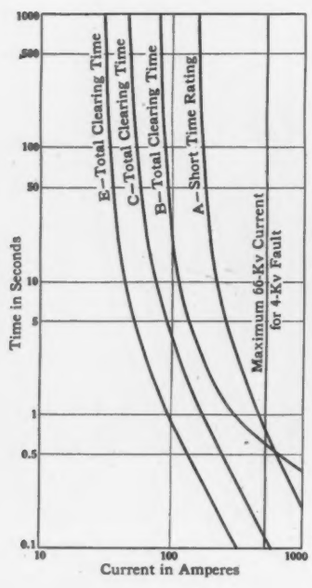


Fig. 3—*These time-current curves provide a coordination chart for the high-power fuse applications in Fig. 2.*

Current Rating—In general, the continuous current rating of a fuse should exceed by about 50 percent the full-load current of the circuit in which it is applied. If the fuse is applied too closely, that is, with the load current near or equal to the continuous current rating of the fuse, unnecessary operations may result, as the fuse link will be heavily loaded and so will be easily blown by a momentary overcurrent. Such an overcurrent might be caused by the starting of a large motor, the charging current of a line or bank of capacitors, or by external disturbances such as lightning.

Exceptions to the 50-percent margin occur where the fuse must be coordinated with other protective devices. The fuse is then applied from considerations of its time-current characteristics, although its current rating must not be exceeded. Sometimes the small size of the fuse, indicated by load-current considerations, makes it desirable to choose a larger fuse to prevent unnecessary fuse blowings by lightning currents such as appear on distribution systems. This is the case with a 1½-kva transformer on a 6900-volt system where a ½-ampere fuse would be ample for the load current, but a 5- or 10-ampere fuse is used to prevent unnecessary outages.

Voltage Rating—A fuse must meet the requirements of insulation to ground and insulation across the blown fuse or the fuse in its disconnected position. Occasionally, special conditions warrant the use of the next higher voltage class of insulation, such as in steel mills where the dirt necessitates 15-kv insulation for 6900 volts. A special case is found where two different supply sources are connected together through fuses and either source is ungrounded. The fuses might blow under fault conditions so that two of the three fuses would be blown and the third unblown fuse would tie one phase of the two systems together. Under these circumstances, if there were no stabilizing force in the two systems tending to keep them in synchronism, part of the time one system would be diametrically opposed in phase to the other system, thus producing twice the system voltage across the blown fuses. Under such conditions, adequate voltage ratings must be chosen.

Physical Limitations—Although most outdoor fuse equipment can be used indoors, the converse is not true. Special precautions are usually taken with outdoor equipment to prevent the placing of voltage across exposed organic insulation, which might be broken down by leakage current. At times, the choice of a fuse is affected by the space it requires. Another consideration is the noise produced by the operation of the ordinary expulsion fuse, which consequently might not be suitable for indoor use. Instead, a totally enclosed fuse would be chosen.

Type of Load—The type of load and the frequency of operation of the fuse affects the choice. For a motor-starting load, such as a rubber mill, where the motor is "inched" and draws its full starting current repetitively during brief periods, a somewhat larger current rating of fuse will be used than would be necessary for a motor under continuous operation, such as a blower. A fuse would be undesirable at a location where a large number of fuse operations would be expected, such as a long line exposed to lightning, falling branches, etc. Here the cost of outages and replacement of blown fuses would be high enough to indicate the use of a circuit breaker.

Overlapping of Fuse Types

A careful consideration of design and performance factors reveals that there is less overlapping of fuses than is generally

believed. When the economic factors are included, it is seen that the overlapping of fuse units is almost non-existent. True, often there are several fuses that will carry the load and meet specific interrupting requirements, but investigation of all the factors indicates clearly the best fuse for a given application.

Fuse Applications on a Typical System

In any application of fuses to a power system, the fuses selected must satisfy four conditions, as follows:

1—The fuse must have adequate interrupting ability.

2—It must meet other physical requirements, such as indoor use.

3—The voltage and current ratings must be suitable.

4—The fuse selected should be the lowest-priced unit to satisfy these conditions.

The several fuse applications in the power system shown in Fig. 2 are designated by letters. The types and ratings of the fuses in each application discussed below are shown in table I. The applicable time-current characteristic for each fuse is shown in Fig. 3.

TABLE I—APPLICATION DATA FOR WESTINGHOUSE HIGH-VOLTAGE FUSES

Classification	Maximum Load Amperes	Fuse Rated Voltage		Interrupting Rating		Indoor or Outdoor Use	Vented or Non-Vented (Condenser)	Size of Highest Voltage Unit Fuse and Mounting		Approximate Cost of Highest Voltage Unit
		Min. Kv	Max. Kv	Amperes at Min. Voltage	Amperes at Max. Voltage			Length Inches	Height Inches	
Boric acid	100	7.5*	23	25 000	15 000	Indoor	Vented	20	14	8
	200	7.5*	34.5	27 500	10 000	Either	Vented	31	18	15
	400	7.5*	34.5	40 000	20 000	Either	Vented	31	20	22
	200	7.5*	34.5	17 500	7 500	Either	Non-vented	33	18	16
	400	7.5*	34.5	30 000	15 000	Either	Non-vented	37	20	25
Current limiting	5	2.5	23	60 000	65 000	Indoor	Non-vented	28	10	11
	10	2.5	23	60 000	30 000			31	10	11
	25	2.5	15	60 000	50 000			25	10	11
	100	2.5	15	60 000	30 000			25	12	20
	200	2.5	5	60 000	60 000			22	8	17
Dropout boric-acid	200	7.5*	69	8 500	4 000	Outdoor	Vented	53	33	20
	200	46	138	9 000	5 000	Outdoor	Vented	90	75	75
Enclosed cutout	50	5 *	7.5	1 200	1 200	Outdoor	Vented	9	6	1
	100	5 *	7.5	3 000	3 000	Outdoor	Vented	11	8	3
Open cutout	100	7.5*	15	2 000	2 000	Outdoor	Vented	16	10	2
Powder filled	½	2.5	23	1 700	100	Indoor	Vented	15	13	4

*These fuse sizes used for 2500 and 5000-volt service.

Fuse A—The dropout boric-acid fuse with an interrupting capacity of 8500 amperes at 69 kv fills the first requirement. It is for outdoor use and so meets the second requirement. The current rating should be about 50 amperes from load considerations, but it is found that a 100-ampere fuse is required to enable the breakers *B* in the unit substation to clear before exceeding the short-time rating of fuse *A*.

Fuse C—Load considerations show that a 300-ampere fuse should be used here. Therefore a 400-ampere, 7500-volt boric-acid fuse holder with a 300-ampere refill would be used. A condenser-type fuse should be specified for indoor service. This fuse has sufficient interrupting ability.

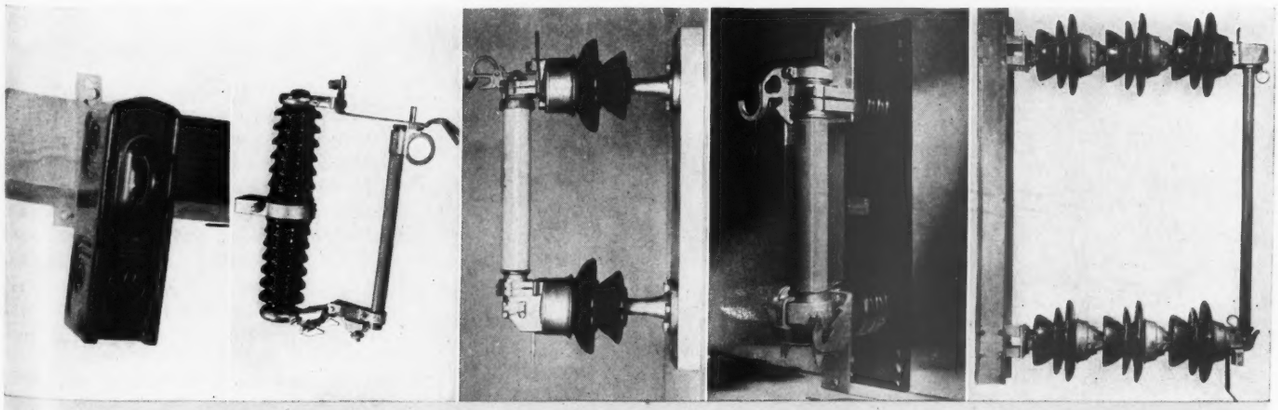
Fuse D—For use as an indoor potential-transformer fuse, the boric-acid current-limiting fuse has more than sufficient interrupting ability and is cheaper than a boric-acid fuse with a refill or a powder-filled fuse together with a current-limiting resistor for potential-transformer protection. The replacement cost of a blown current-limiting fuse is higher, but this factor is of small importance as the metering equipment should not lead to frequent fuse blowings.

Fuse E—The 7500-volt dropout boric-acid fuse would have sufficient interrupting capacity as an outdoor power fuse because it is rated at 8500 rms asymmetrical amperes. A 200-ampere rating is indicated by load considerations.

Fuse F—Line reactance limits the fault current to about 1600 amperes at this point. This would allow the use of a cutout that must be of the 100-ampere rating to have sufficient interrupting capacity. Either the open or enclosed type could be used. Probably the enclosed type would be chosen as it is on a circuit where most of the other apparatus is of the insulated type for the reduction of hazard to linemen. No smaller than a 15-ampere link would be used.

Fuse G—The fault current here is only 600 amperes so that a 50-ampere cutout would be used. Nothing smaller than a 5-ampere link should be used in order to prevent frequent outage caused by surge currents.

Of course, the above typical fuse application is greatly simplified from the conditions which obtain in actual service. However, when the rules given are applied, they will usually indicate a specific fuse for any given application problem. If there is any question about which of two fuses is to be used, the economic factor should be eliminated and the fuse chosen only on its functional considerations because the value of insurance far outweighs small differences in cost.



Enclosed-type cutout. Open-type cutout. Vented boric-acid fuse. Current-limiting fuse. Dropout boric-acid fuse.

Typical examples of the several classes of high-voltage fuses whose characteristics are given in detail in table I.

What's New!

The Furnatron—An Electronic Furnace Control

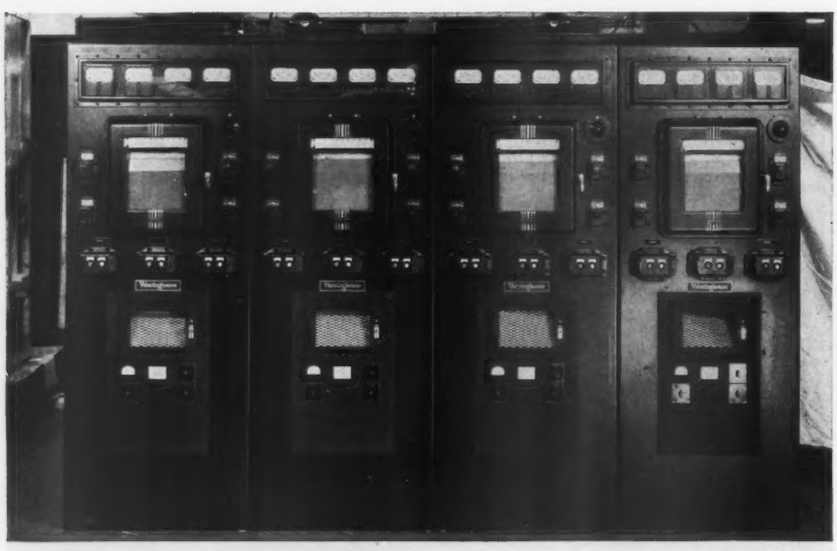
PRECISE temperature control in heat-treating furnaces is needed in the production of new alloys, in chemical processes, in fact in almost every modern industry at some point. A new control, using the reliable and rugged saturable reactor in combination with the precision of the electronic tube for regulating the heating current, provides a temperature constancy unaffected either by the rate of material flow in the furnace or fluctuation of the line voltage.

Obviously, if more cold material is placed in a furnace, the temperature drops unless the greater load is met by increased input to the heater units. This is tended to automatically by the Furnatron. In this new control, a pyrometer and slide wire potentiometer, a saturable reactor, and a thyraton-controlled d-c source for the saturable reactor comprise the essential components. If the slide-wire potentiometer that forms a part of a bridge circuit is set for the desired temperature and conditions cause the temperature to drop, an unbalance is produced in this circuit. The firing angle of the thyratron tube is changed so that the d-c component in the saturable reactor increases with the resultant increase in the a-c flow in the heating units. This continues until the pyrometer shows a balance has once more been reached. The reverse takes place when the temperature rises.

Another factor in temperature control is line-voltage fluctuation. This is a serious factor because in some installations the power dissipated is roughly proportional to the third power of the line voltage and small variations greatly affect the furnace operation. Further, a change in the line voltage changes the d-c saturating current and hence the reactance of the saturable core reactors. An increase in the line voltage will cause a decrease in reactance and will thus supplement the initial increase in the heater load current.

A compensating circuit, made part of the regulator circuit, so operates that the saturating current supplied by the regulator is made to vary in the opposite direction from the variation in the line voltage. The a-c load current in the heaters will be constant if the rate of change of saturating current with line-voltage variations is properly adjusted to the characteristics of the saturable core reactor.

The Furnatron is adaptable, not only to metal-industry processes but to gas temperature control as encountered in the synthetic rubber or other chemical industry applications. It is applicable to single- or three-phase installations.



This electronic furnace control compensates for thermal-load and line-voltage variations.

A New Accelerometer Amplifier

THE successful development of a quartz-crystal accelerometer for measuring extremely high rates of acceleration* has opened new avenues of investigation. To record adequately shock and other phenomenon, it is necessary to use the crystal accelerometer in conjunction with a magnetic oscillograph. The minute signals from the accelerometer not only must be amplified, but also its high-impedance output must be matched to the low-impedance input of the magnetic-oscillograph element. A new two-stage, push-pull vacuum-tube amplifier is now available to amplify signals from high-impedance sources to give enough power to operate recording apparatus with low-impedance input.

The frequency response of the amplifier is linear from five to 2000 cycles per second. The rated output, 0.5 volt, 300 milliamperes, is secured with a minimum input voltage of two volts. The input impedance is 250 000 ohms and the output impedance is 1.75 ohms.

A low-impedance output amplifier, the new unit is completely self-contained.

The power supply for the amplifier operates from a 110–120-volt, 60-cycle, a-c source. The total power consumption of the amplifier is 40 watts.

The amplifier can be used with any high- or low-impedance source up to 100 volts. It can be used to amplify the output of strain gauges, accelerometers, and other comparable apparatus.

The unit is self-contained with a built-in power supply. The overall measurements are 19 inches long, seven inches wide and nine inches high. It weighs but 25 pounds and is provided with handles for easy portability.

Westinghouse Engineer, February, 1943, p. 17.

Radio-Frequency Generators

POSSIBLY one reason the utilization of high-frequency generators has been delayed until recently has been psychological. Engineers trained in the power school have looked upon an oscillator as a discouraging collection of wires, coils, tubes, capacitors, and a mystery that could be unraveled only by those educated in that "foreign" subject, electronics. It now appears that order has been brought out of this seeming chaos that has been high-frequency generators. A family of oscillators intended for a wide variety of industrial uses has been produced by Westinghouse that is no more formidable in appearance than a beautifully finished console radio receiver, that are almost as simple to operate, and in whose

design has been fused the reliability, and many of the construction features to which industry is accustomed.

A great many high-frequency heating loads, both induction and dielectric heating, can be accommodated by units of one- to 20-kw capacity. These are standardized units. Units of 50- to 200-kw capacity involve complex problems in applying them to industrial processes and are made to order.

The radio-frequency generators are mounted in neat cabinets to which considerable attention has been given to appearance. The stock units are completely self-contained, i.e., they require only electrical connection to a 60-cycle power supply and have no external cooling or other auxiliaries. The primary voltage is 220 or 440 volts, depending on the rating of the unit. Housed in the single cabinet are the oscillator, power supply, blower, and necessary switchgear. The radio-frequency

Frequencies of 5, 15 and 30 mc at two kw are supplied by this new generator.

section is completely shielded to minimize the possibility of interference with nearby communication circuits. An automatic timing control permits load-cycle adjustment to a predetermined time, which can be automatically repeated. Terminals are provided for remote control.

Air-cooled tubes are used in the standardized generators. Their use eliminates bulky water-cooling equipment and allows complete portability of the 2-, 5-, and 10-kw units and increased portability of the 20-kw unit. The air blower for cooling the tubes provides a circulation of air throughout the entire equipment, insuring a greater factor of safety and permitting a reduction in size.

The radio-frequency oscillating circuit varies with the kilowatt rating and frequency needed. For capacities through 20 kilowatts, the circuits selected entail the least number of controls, are simple to adjust and operate and have greatest overall efficiency. In this type of circuit, the frequency shifts as the characteristics of the load change during the heating cycle in such a manner that the load on the tube anode tends to approach unity power factor. This provides the most efficient operation over the entire heating cycle. In the two-, five- and ten-kilowatt generators, the load can be coupled to the work without the use of an external impedance-matching network when the work and generator are close together. A separate network is available for greater distances to the work and for use with the 20-kilowatt unit.

The frequencies available in this line of generators are: 450 kilocycles, 2 megacycles, 5 megacycles, 10 megacycles, 15 megacycles and 30 megacycles. However, all frequencies are not available in all generator output ratings. The two-kilowatt generator is available for 5, 15 and 30 megacycles; the five-kilowatt for 450 kilocycles, 5, 15, and 30 megacycles; the 10-kilowatt for 450 kilocycles, 5, 15 and 30 megacycles; the 20-, 50- and 100-kilowatt units for 450 kilocycles, 2- and 10-megacycle operation.

Single-phase, full-wave mercury-vapor rectifiers provide the anode current for generators under 10 kilowatts. For capacities of 10 kilowatts and larger, a three-phase, full-wave rectifier, utilizing six mercury-vapor tubes is used, giving even distribution of power demand, reducing conductor size and providing better voltage regulation. Time-delay switches are standard on all rectifiers. Step starters are used on the 20-kw capacity unit and those larger to safeguard the rectifier tubes from high transient voltages while starting and reduce the danger of flashovers in the work circuit arising from starting surges.

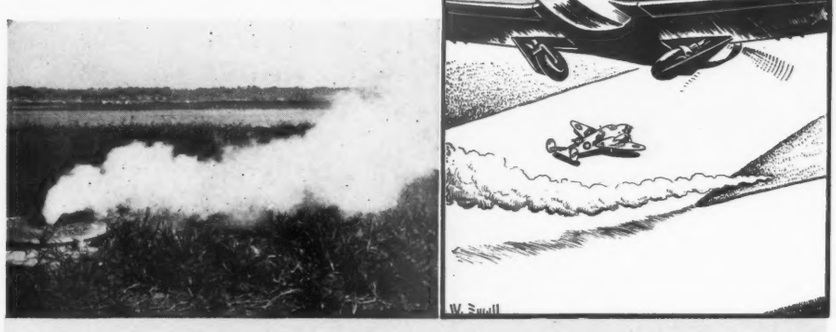
Smoke Tells a Story of Safety

STRAWS showed the way the wind blew to the ancients. Latterly, aviators have made use of the wind sock, a cone of fabric that showed in some measure the direction and velocity of the wind. Its many lacks, however, led to the development by Westinghouse of the smoke generator to supplement the information conveyed by the wind sock. The generator provides a ribbon of smoke that floats with the wind across the field and tells the incoming aviator much about air conditions he will encounter close to the ground.

It is important to have information on the wind direction and velocity at the point where the incoming plane makes contact with the ground as many gust-inspired ground loops attest. The standard wind indicators—wind sock, weather vane, etc.—do not do this. They require a mounting structure that prohibits placing the indicator on or near the field. Usually, they are mounted on the administration building or a hangar. In a large field, this means that the indicator may be 50 feet above ground and several hundred yards from the landing end of the runway. A decided difference can exist between the air conditions at the location of the usual indicator and the point of landing on a large field.

The principle of the smoke generator is simple. Oil is vaporized by heat to form a thick smoke. It uses the same type of electric immersion heater that is used to heat baby's milk, a heating coil within a tube. Instead of milk, clear oil similar to Diesel fuel is used. The heater is partly immersed in the oil. Oil is splashed by a small blower against the portion of the heater protruding from the oil. The upper exposed portion of the heater is hot, instantly vaporizing the oil as it strikes the hot metal. The resultant plume of oil smoke emerges from an outlet flush with the ground and drifts across the field, its size and shape depending on the wind.

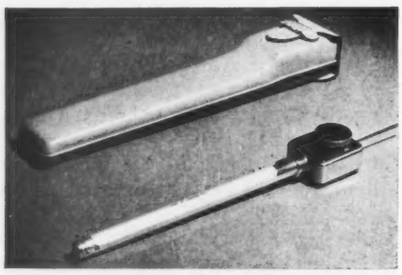
The smoke generators have no superstructure, the entire apparatus being buried. They can, therefore, be spotted about the field at runway intersections as the requirements of the field dictate. The emerging ribbon of smoke is from 20 to 40 feet long and visible from two to three miles. Not only does it indicate the direction of the wind close to the ground and at the landing strip, but also the nature and force of any cross gusts of wind. The night visibility of the smoke is excellent on fields with overall flood lighting. It is



The smoke generator can be put in the landing area without danger to incoming planes.

not satisfactory under ordinary contact lighting arrangements because the light from the contact-type lamps lies too close to the ground.

The smoke generator is a self-contained, automatic unit. It consumes about one quart of oil per hour. An oil reservoir is sunk near it and the oil level in the generator is kept constant by a special valve. The heater itself dissipates one kilowatt in heating the oil and the air and vaporizing the oil splashed against its side. The blower is of the Serroco type with a 30-cubic-feet-per-minute capacity. The heating unit and blower operate from a 115-volt supply. The unit is operated by push-buttons in a low-voltage circuit from the control tower and is in full operation within five minutes in cold weather and two minutes in warm weather. The smoke generator is left in operation continuously or turned on and off at will from the control tower, its manner of operation depending on flight-traffic conditions.



Handy to carry as a slide rule, a Vibrometer is direct reading, easy to use.

The "Slide-Rule" Vibrometer

MANY are the devices for plumbing the ills of vibration. One of the simplest, brought out in 1941*, is the adjustable vibrating-reed Vibrometer, which gives frequency readings directly on a scale in the handle.

Essentially, it is a cantilever—suspended metal reed clamped between rollers. This type of mounting offers least damping effect and permits easiest adjustment of the length of the reed. When the head of the instrument is placed on the vibrating body and the adjusting knob rotated until the reed is in resonance, the reed vibrates at its maximum amplitude. It is sensitive to vibrations whose amplitudes are as small as one ten-thousandth of an inch. These amplitudes are magnified approximately 500 times.

Refinement in design has resulted in a slight decrease in weight and simplification of its application and use. It weighs but eight ounces. Responsive to vibrations from 500 to 20 000 cycles per minute, the Vibrometer provides a quick and simple method of assaying a mechanical-vibration problem within the frequency spectrum normally encountered.

*Westinghouse Engineer, May, 1941, p. 30.

Finale for Flickering Fluorescents

WHEN a fluorescent lamp winks and blinks at the end of its useful life, the action is not only annoying but detrimental to the ballast and starter. An incandescent lamp quits with finality when the filament burns out. The fluorescent lamp, on the other hand, depends on a mercury discharge within the tube for its operation and fails to function when this discharge can no longer be sustained. The starter necessary for its operation, however, keeps trying to strike the arc and causes the blinks. The new, no-blink starter performs the necessary function of starting the operation of the fluorescent lamp and stops it when the lamp is no longer usable.

A fluorescent-lamp starter is primarily a glow-discharge tube in series with the lamp electrode-heating filaments that conduct current until the mercury discharge action is initiated. In the no-blink starter a resistor and bimetal switch are put in series with the starter element. When the lamp is in good operating condition, the starter functions normally; it merely provides a larger starting current during the time necessary to start the lamp. However, when the lamp fails, the repeated attempts of the starter to start the lamp cause current to flow in the resistor sufficiently long to heat the bimetal switch that opens the circuit. This action places another resistor across the line to keep the bimetal hot (and the lamp-circuit open) until the fluorescent lamp is replaced. The starter then automatically resumes normal operation. The wiring diagram in Fig. 1 shows how current flow through the lamp is reduced.

Intricate yet rugged, the no-blink is the same size as the old-type starter.

The no-blink starter is entirely interchangeable with ordinary starters without any change of the receptacle. It is exactly the same size and, as the additional parts are all self-contained, no change in wiring is necessary. The starter is available in two sizes, for 40- and 100-watt lamps.

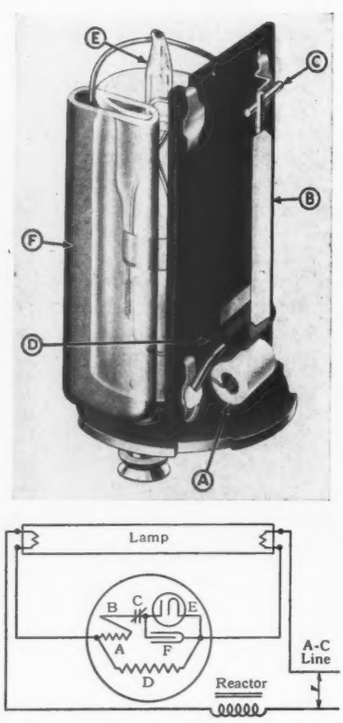


Fig. 1—*An artist's sketch and a wiring diagram of the no-blink starter showing the several parts and their relation to each other.*

When operating normally, upon closure of the lighting switch, the gas in the glow tube *E* ionizes and a glow discharge occurs which generates heat and causes the bi-metal switch in the tube to close. This closure completes a circuit through the lamp filament, starter and ballast causing sufficient current to flow to heat the lamp filaments. When the switch in *E* closes, the glow discharge in *E* stops and the bi-metal switch opens. When the switch in *E* opens, there is an inductive kick from the reactor that strikes the arc across the fluorescent tube, starting the mercury discharge action, and the lamp lights. The voltage drop across the lamp is then less than the voltage necessary to break down the gas in tube *E* so that current flows through the lamp only. The switch in tube *E* remains open, therefore no current flows through the starter. Obviously, if the lamp is deactivated and the arc is not struck, the current again flows through the starter and the cycle is repeated over and over. The new elements, *A*, *B*, *C*, and *D* in the no-blink starter prevent this. However, should the lamp fail to light, current flowing repeatedly through resistance *B* heats bimetal switch *C* so that the circuit is opened. Resistor *D* across the starter and in series with the filaments maintains this temperature of the bi-metal switch and the switch remains open. When a new tube is installed, the starter functions normally. The current flowing through resistor *D*, when the lamp is running, is small, as the resistance of *D* is about 50 000 ohms.

PERSONALITY PROFILES

IT IS interesting to observe the careers of engineers following graduation. Some follow the chosen branch of engineering unswervingly. Others progress from one specialty to another, using each in turn as a stepping stone to the next, but for the most part leaving the past behind. A few, as they grow in experience, simply spread

their interest to new fields, without ever dropping the old. They become broader in their engineering scope as they accumulate experience. *A. C. Monteith* is one of these. Born in Northern Ontario, he obtained his engineering education at Queens University at Kingston, graduating in 1923—striking out immediately for Westinghouse. Upon completing his graduate-student course there, he entered the group working on central-station problems. His first specialty was powerhouse auxiliaries. Although he left that specific branch years ago, he can still discuss its problems expertly. Later, his attention turned to transmission-line problems, specifically lightning protection, and even more specifically, de-ion protector tubes, in which he is still a recognized authority although he has successively become Westinghouse Central Station Engineering Manager and is now manager of its entire Industry Engineering Department, which includes not only the industry producing electrical power but also the many industries that use it. Always willing to enter new fields, Monteith has taken on industrial electronics, acting as coordinator of this large and widely spread field of engineering for the Westinghouse Company. With his big frame and hearty laugh "Monty" is a familiar figure on the speaker's platform, in committee rooms, and "bull sessions" wherever engineers convene.

* * *

GRADUATING from the University of Pittsburgh in 1935 with the degree of B.S. in Physics and Engineering, *J. M. Wallace* varied the usual procedure by not taking the student course when he came with Westinghouse. He immediately went to work in the high-power laboratory. His subsequent activities took him on a tour of duty through the high-voltage, direct-current, and impulse laboratories. In 1937 he became identified with the Switchgear Engineering Department and has been so engaged from then on. Recently, he has been made head of his section. During this period he has co-authored four papers on protective devices. Wallace, as a pianist, finds classical music easier than Boogie-Woogie, but he is working hard at both. When he sets sail in his canoe, literally, he really churns the waters of the staid Allegheny. Carrying 75 square feet of sail on a canoe is a feat that requires the finesse of such a sailing enthusiast as Wallace.

* * *

IT IS THE second appearance on these pages for *H. L. Rawlins* (February, 1943) who again writes on his specialty, protective devices. He received both his B.S., E.E. ('26) and M.S., E.E. ('27) at

Ohio State University. Coming to Westinghouse in '27 in the Switchgear Engineering Department, he advanced first to the position of Section Engineer, then to Assistant Manager, and recently to Manager of Protective Devices Engineering. Rawlins' interest in his chosen work does not stop with the five o'clock whistle. For some years he has been active in serving on AIEE sub-committees. He has a large number of patents to his credit and when you see him in his home at ten PM in a characteristic pose with his feet on his desk and a cross-section pad in his lap, you know another protective-device patent is aborning.

* * *

JUST AS some horticulturists work to develop strains of grains that can better endure the vigors of certain climates, *G. L. Moses* has devoted his energies to improving the endurance of insulation. In the last seven years in the insulation development section of the Transportation and Generator Department at Westinghouse, of which he is now in charge, he has made studies and directed the research of others on thermal conductivity of insulation, insulation resistance, effect

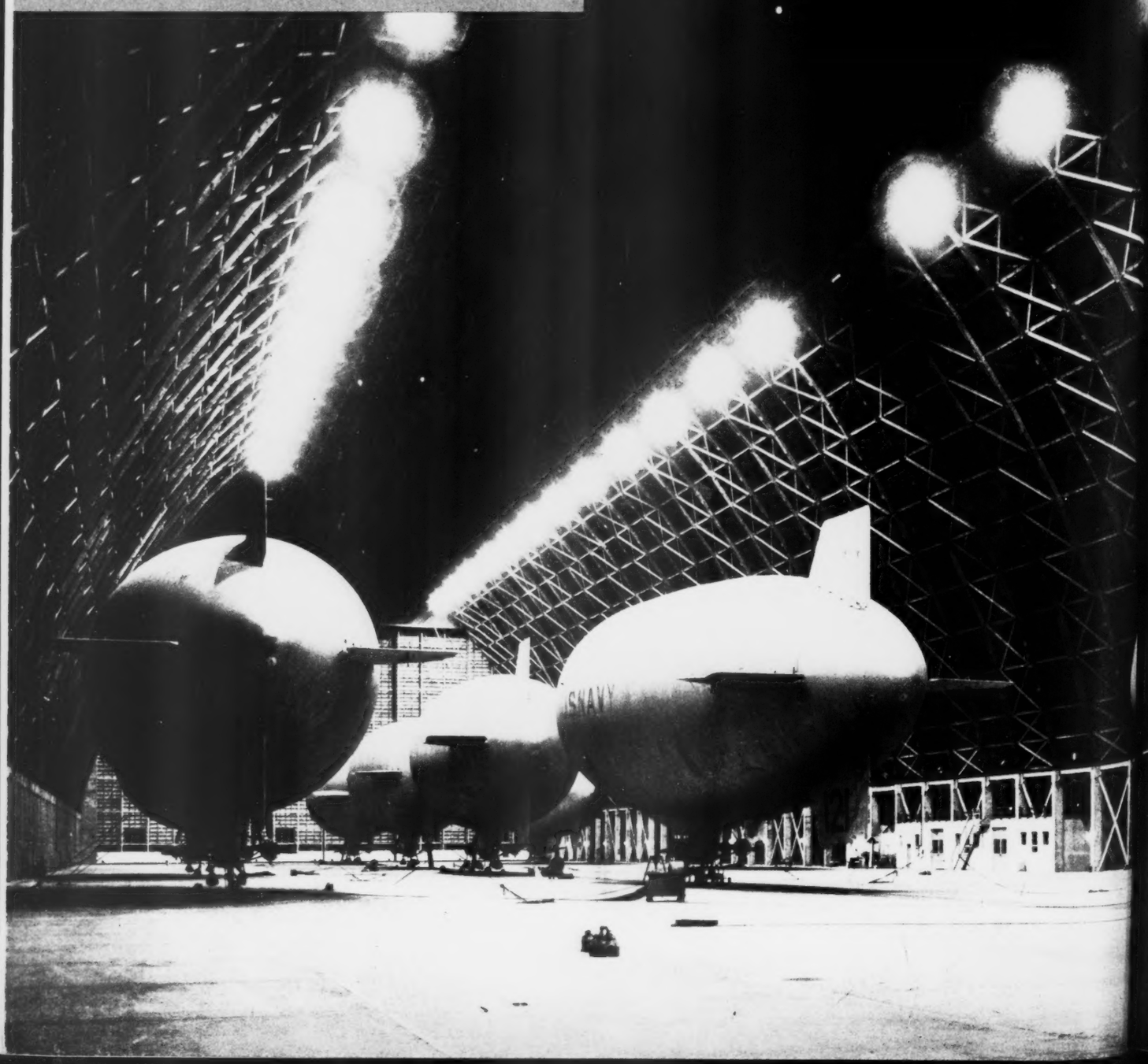
of temperature on life of insulation. This last has culminated in the analysis of the amazing new family of high-temperature insulations he presents in this issue. Moses has been with Westinghouse since graduating from Bliss Electrical School in 1923, working first in Railway Sales, followed by an eight-year turn in Renewal Parts Engineering, and five years in Railway Engineering Control. When asked about his avocation, he smiles wistfully and says he used to play tournament bridge but it has been so long now he would probably be guilty of trumping his partner's ace.

* * *

ANOTHER repeater in this issue is *W. H. (Bill) Kahler* (August, 1943). To him lighting is a science and an art—a science because it must be engineered for the efficient operation of the complex eye mechanisms, an art because it must create moods favorable to the well-being of many types of people. He was graduated from Brown University in 1936 with a degree of B.S. in E.E. During his college years he also did electrical contracting work and supervised the restoration and construction of a series of models of early American homes for the Rhode Island Tercentenary Commission. His new house (which is strictly modern) is often the guinea pig for lighting "brainstorms" because he sees the necessity for great improvements in present-day house-lighting technique. At present, Kahler is waging the annual battle with the local rabbits for the rights of eminent domain in his extensive victory garden.

High Lights

FOR HIGH BUILDINGS

New "suns" shine in the firmaments of such huge structures as blimp hangars, airplane factories, and steel mills. Three-kilowatt mercury lamps provide high levels of lighting with great economy of current, number of units, and amount of copper (see p. 144).

U. S. Navy Photo